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Editorial First Issue

With this first issue, we are very pleased to announce the launch of the International Journal of Research in Applied Sciences, sponsored by GITA Autonomous College, Bhubaneswar.

The International Journal of Research in Applied Sciences (IJRAS) aims to address this need and to be the main international forum for publishing papers on applied sciences and the journal intends to primarily publish papers from various disciplines illustrating different emerging technologies with real world applications.

The IJRIAS will be published bi-monthly. The abstracts of the published papers, and sometimes the full papers will be available on-line on the journal page of GITA website: www.ijras.in. The journal will contain original research papers on the topics listed in "Aims and Scope". Each paper will be thoroughly reviewed by independent reviewers.

Thanks are due to many people who have helped in starting up this new journal. We are particularly grateful to the Management of our institution, who provided us with a lot of support and advice. Further, we are also very much thankful to all our esteemed advisors, who will continue to Support us to represent the journal in their research areas. We are sure that their reputation and great expertise in the field will have a significant contribution in shaping up the journal and making IJRIAS a prestigious international journal.

It is also our great pleasure to welcome the members of the Editorial Board of IJRAS. We rely on their expertise for reviewing and accepting papers to the journal. Therefore, their contribution to the journal is invaluable and we are grateful to them for giving freely of their time to review papers for the journal. We hope they will continue to help us in the future.

We are convinced that with this unreserved support from such a prominent and large team of researchers the IJRIAS will become one of the most prestigious journals in the general area of applied sciences. We are fortunate to work with this team.

Finally, the Editors-in-chief wish to thank the authors who submitted papers to the first issue of IJRAS.
Any suggestion on how to improve our activity in order to deliver a better journal to the authors, readers and subscribers of this journal will be always very much appreciated.

Prof. (Dr.) Parimal Kumar Giri
December, 2023, Editors-in-chief

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CONTENTS

A Deep Learning Framework Based on Convolutional Neural Networks for the Identification of Eye Melanoma

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Abstract:

Eye melanoma is the most prevalent kind of cancer, while being an uncommon condition. Eye melanoma is a major therapeutic issue, and like other cancers, it is usually treatable if detected early enough. However, the diagnosing procedure is difficult. This study outlines an automated convolutional neural network (CNN) method for detecting eye melanoma. From a conventional database, we use 170 pre-diagnosed samples that are put into the CNN architecture after being pre-processed to reduce their resolution. For the diagnosis of eye melanoma, the suggested approach eliminates the requirement for separate feature extraction and categorization. Despite needing a large amount of computing, this method performs better as compared to eye melanoma detection with an artificial neural network (ANN) achieving a high accuracy of 91.76%.

Keywords: convolutional neural network (CNN), artificial neural network (ANN), pre-processing, deep learning, and eye melanoma

1. Introduction

One of the most lethal types of cancer is eye melanoma [1-2]. The National Cancer Institute (NCI) states that carcinoma, a kind of eye melanoma, frequently affects young adults. Ocular, or eye, melanoma is the rarest form of these cancers, despite the fact that they are a common source of malignancy. If melanoma is detected at an extremely early stage, patients have a 95% chance of surviving. However, the disease's detection is equally uncommon and challenging as ocular melanoma itself. This kind of cancer is caused by the melanocytes found in the choroid, eye, or ciliary body. Almost 85% of these cases involve the posterior choroid. Anterior uveal melanoma is linked to the eye, ciliary body, and anterior choroid. According to studies, about half of individuals with uveal melanoma go on to develop metastases, making this carcinoma a dangerous and difficult cancer to treat.

Uveal melanoma manual diagnosis calls for highly skilled professionals with outstanding observational abilities. Consequently, there may be variation in the diagnosis. Recent developments in research have looked to artificial intelligence (AI) for help in light of these difficulties [3]. Medical decision-making processes pertaining to uveal melanoma can incorporate the outcomes of AI's promising performance in prospective clinical settings. Lung cancer has been successfully detected and classified from tomography images using conventional AI-based technologies [4]. Additionally, AI-based methods have been used to diagnose breast cancer [5]. Furthermore, image registration techniques, which feed an artificial neural network (ANN) with characteristics from the gray level co-occurrence matrix, have also been used to diagnose breast cancer. Both support vector machines (SVM) and artificial neural networks (ANN) have been used in [6] to classify liver cancer. According to comparative findings, SVM typically performs

better in this situation than ANN. Ahmed et al. [7] introduced an artificial neural network (ANN)-based method for detecting eye melanoma, which leverages image features and achieved an accuracy of 85%. The convolutional neural network (CNN) [8–9], an advanced form of the artificial neural network (ANN), is inspired by the human nervous system. CNNs can identify cancerous tumors in the eyes if they are properly trained. The main functions of CNNs are image classification and scene object identification. Because of these characteristics, CNNs are quite useful for identifying ocular melanoma.

Recent studies have demonstrated the superiority of AI-based diagnostic procedures, especially those that employ CNNs. CNNs are more sensitive and specific than manual detection techniques. CNNs can speed up the diagnosis process for dermatologists and ophthalmologists, perhaps assisting in the early detection of cancers.

This study describes a deep learning system designed to automatically detect eye melanoma using a convolutional neural network (CNN). Much like conventional artificial neural networks (ANNs), CNNs consist of one or more convolutional layers, pooling layers, and fully connected layers. The main advantage of CNNs is that they require fewer parameters and a shorter training process than ANNs with an identical number of hidden layers. With an accuracy rate exceeding 6%, the proposed method beats previous studies despite demanding a large amount of processing resources.

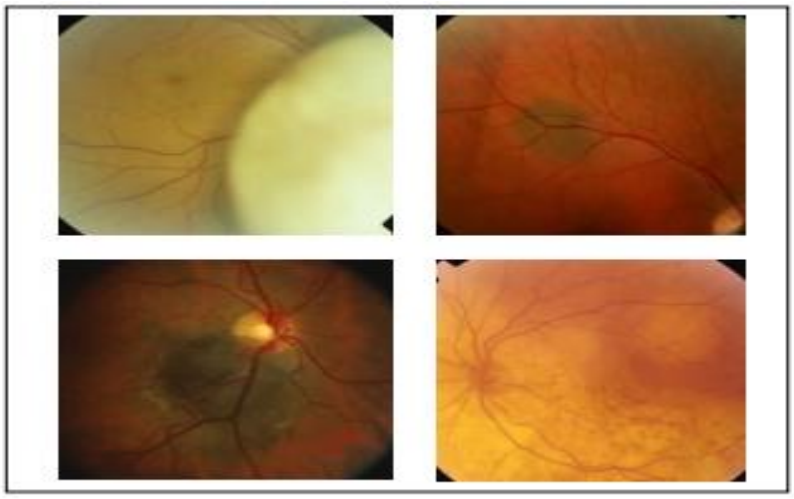

Fig. 1. Ocular images with choroidal melanoma obtained from [10]

2. A thorough explanation of the work

The approach put forward features a layered structure similar to conventional neural networks. Each layer within the network serves a specific function for training under supervision, as well as the training procedure is conducted using deep learning techniques. Deep learning's capacity to automatically extract and add new features from the training dataset is a significant advantage over conventional artificial neural networks (ANNs) and other machine learning technologies. The New York Eye Cancer Center database provided the eye melanoma photos used in this investigation [10]. Medical professionals assess and verify each photograph to determine if it shows eye melanoma's evidence. These pictures create the input dataset, which is then pre-processed and fed into a CNN structure. The network's layers learn a large number of characteristics from the training dataset, and the final layers classify the features into appropriate groups as either

melanoma or non-melanoma images. The suggested scheme's flowchart is shown in Fig. 2 below. For the identification of eye melanoma, the suggested method does away with the necessity of distinct feature extraction and classification procedures. Rather, categorization is carried out within the same integrated framework by the convolutional neural network (CNN), which immediately learns and extracts pertinent information from the images.

The whole ocular melanoma detection procedure is shown in Fig. 3, with pre-processing and the CNN architecture described in the following subsections:

Image pre-processing

There are 170 pre-diagnosed photos with different resolutions in the training dataset. All of the photographs are manually scaled to a consistent resolution of 200×200 pixels in order to get them ready for the deep learning framework. To accomplish the decreased resolution, the middle region of each eye image is cropped, and the cropped area is then proportionately resized. The deep learning model's efficacy is increased and consistency is guaranteed by this standardization.

3. CNN architecture

CNNs have been effectively used in the automated diagnosis of cutaneous melanoma [12], heart failure [11], and other medical conditions. CNN models have recently been used by researchers to technology-driven diagnosis systems for tracking a variety of illnesses. Table I shows the structure of the CNN, which is made up of the following layers:

a) Input layer: This layer receives as inputs the processed images with a 200x200 pixel resolution.

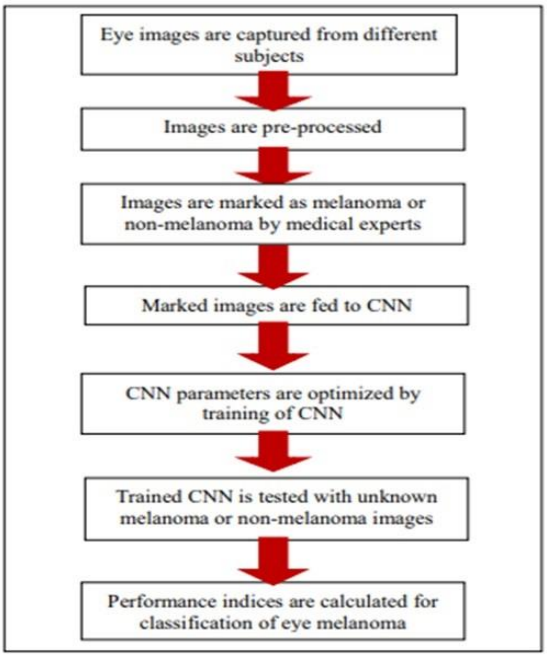

Fig.2. Diagram of the proposed system's workflow

b) Convolution Layer (Conv): This layer applies convolution operations to the processed images, extracting key characteristics and conveying the information through the network layers.

c) The following is an expression for the image convolution operation:

$$(f * h)(x, y) = \sum_{q=-\infty}^{\infty} f(p, q).h(x - p, y - q)$$

where: f(x,y) represents the refined image,

- h(x,y) represents the filtering kernel, with dimensions of 15×15 and 8×8, respectively. This operation involves sliding the filter hhh over the image fff to produce feature maps that highlight important patterns and structures within the images.

  Eight kernels were utilized to extract specific features from the images. The parameters of these kernels are initially set randomly and are updated through the backpropagation learning process. This iterative adjustment of weights allows the convolutional neural network (CNN) to refine its ability to detect and represent relevant features in the images.

c) Rectified linear unit layer (ReLU): This layer adds non-linearity to the convolutional layer by acting as an activation function. Every element is subjected to a thresholding procedure, which sets any value below zero to zero.

$$f(z) = z \quad for\ z \geq 0$$
$$= 0 \quad \text{otherwise.} \qquad (2)$$

d) The max pooling layer (MP) splits the convoluted images into rectangular regions and gives the maximum value from each zone in order to carry out the pooling operation. We call this approach max pooling. The pooling procedure shifts by 2 pixels at a time when the stride for this layer is set to 2, reducing the spatial dimensions of the feature maps while preserving the key features.

e) The fully connected layer (FC) is comparable to an artificial neural network (ANN) layer in that every neuron is connected to every other neuron from the non-linear layers that came before it. The Fully Connected (FC) layer is the name given to this layer. Through the integration of features acquired by the previous layers, the FC layer is in charge of carrying out categorization. The FC layer employs the learnt features to make final classification judgments, whereas the preceding layers concentrate on feature extraction and learning.

The backpropagation approach is used in conjunction with stochastic gradient descent (SGD) training to update the kernel weights and reduce error. To get the desired performance, the backpropagation method is run seven times in this article. An i5-4460T processor with 16 GB of RAM and a 4 GB NVIDIA GTX graphics card is used to train CNN.

4. Experimental Results

An eye cancer dataset is used to assess the effectiveness of the suggested approach. There are 170 ocular melanoma photos in this dataset, taken in different ways. Each image in the dataset is annotated and classified as either melanoma or non-melanoma by medical specialists.

The performance of the current study is assessed using performance metrics include positive and negative projected values (PPV and NPV), sensitivity, specificity, and accuracy. Equations (3–7) provide their expressions.

Model training uses sixty percent of the dataset, whereas testing uses the remaining forty percent. To determine if the ocular images are normal or melanoma, the outlined network generates output values between 0 and 1. For ocular melanoma, the target values are [1 0] ^{T}, while for normal images, they are [0 1]^{T}. Therefore, [1 0]^{T} is the ideal CNN output for melanoma, whereas [0 1]^{T} is the perfect CNN output for normal pictures. The values obtained for melanoma in practice are [0.83 0.17] ^{T}. Depending on the threshold in table III, at the output, a thresholding procedure is carried out to change values to either 1 or 0.

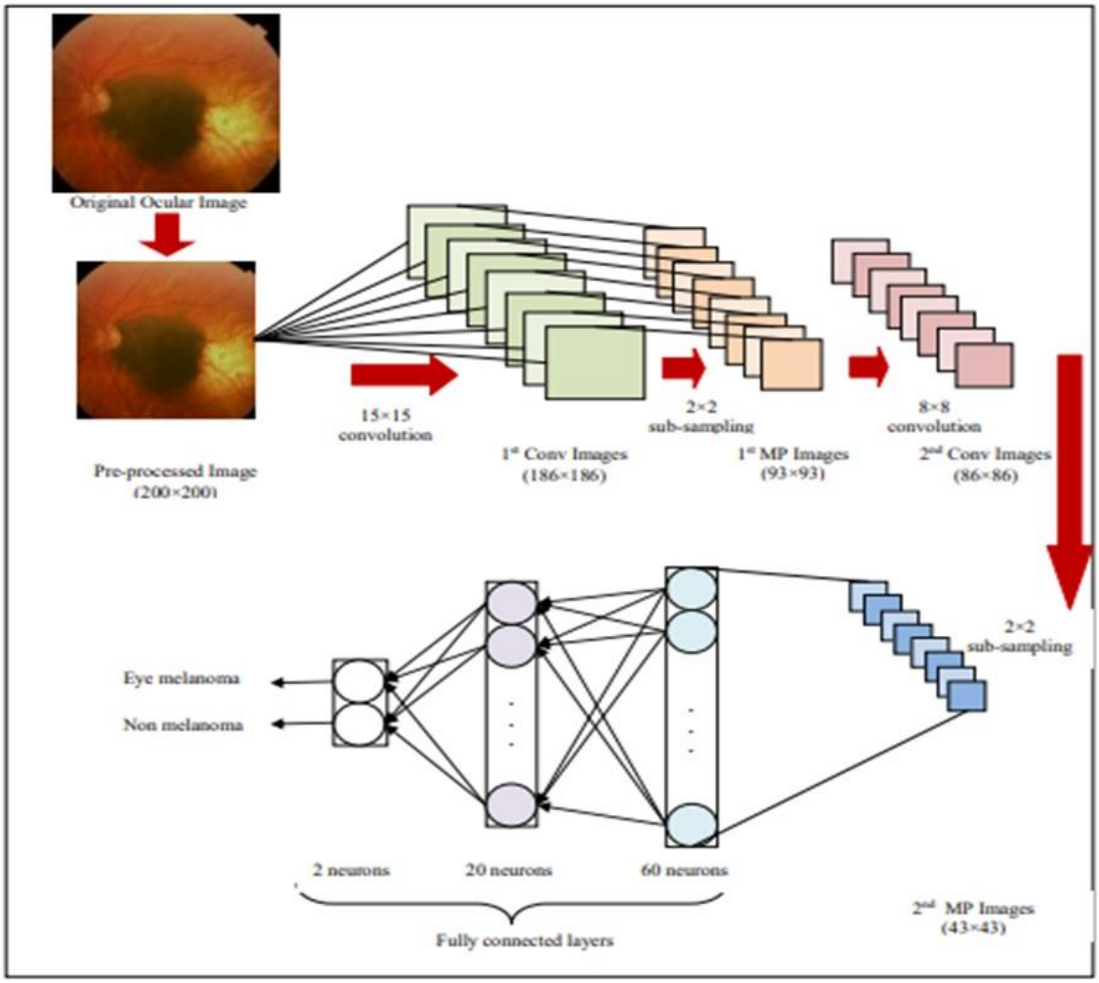

Fig. 3. Diagram of eye melanoma detection with a CNN

Table 2. Matrix of Confusion for the Suggested Method

Results	**Truth**	
	Eye-melanoma	**Not-melanoma**
Eye-melanoma	99(True Positive)	3 (False Positive)
Not-melanoma	11 (False Negative)	57 (True Negative)
Total	110	60

Table 2. Performance Comparison with Previous Work

Methods	Accuracy	Specificity	Sensitivity
Ahmed et al. [7]	85%	90%	80%
Proposed	91.76%	95%	90%

$$\text{Accuracy} = \frac{TP+TN}{TP+FN+FP+TN} = 91.76 \quad (3)$$

$$\text{Specificity} = \frac{TN}{TN+FP} = 95.00 \quad (4)$$

$$\text{Sensitivity} = \frac{TP}{TP+FN} = 90.00 \quad (5)$$

$$\text{PPV} = \frac{TP}{TP+FP} = 97.05 \quad (6)$$

$$\text{NPV} = \frac{TN}{TN+FN} = 83.82 \quad (7)$$

In the CNN, the training parameters are provided in Table IV.

5. Conclusion

This article describes a convolutional neural network (CNN)-based deep learning strategy for the automated diagnosis of eye melanoma. Prior to being fed into the CNN architecture, ocular images undergo pre-processing by being downsized to a constant resolution. The proposed method eliminates the need for separate feature extraction and categorization, hence simplifying the procedure. With an accuracy rate of 91.76%, the method exceeds previous research that used artificial neural networks (ANNs), despite consuming a significant amount of computing resources.

Table 3.Training Parameters for CNN

Parameters	Attribute/Parameter Value
Loss Function	Logarithmic loss
Learning Algorithm	Randomized Gradient Descent
Hyper-parameter	Momentum(0.9)
Batch size	85
Starting learning rate	0.001
Maximum training cycles	50

This study's primary goal is to provide a straightforward, an accurate and non-invasive technique for the automatic detection of eye melanoma. Future studies should focus on using deep learning tools to apply these automated techniques to the diagnosis and classification of iris cancers in order to improve treatment accuracy and patient survival rates.

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A new way to use the Linear Ranking Function to solve Fuzzy Number Shortest Path Problem

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Abstract:

The traditional Dijkstra algorithm is modified in order to solve the shortest path issue on a network. In this particular implementation, a trapezoidal fuzzy integer is utilized for the arc length rather than a real number. Through the utilization of the liner ranking function that was proposed by Maleki, trapezoidal fuzzy numbers are defuzzified. A numerical evaluation of the suggested approach is performed on a large-scale random network.

Keywords: Trapezoidal Fuzzy number, Linear ranking function, Dijkstra's algorithm.

1. Introduction

The fuzzy shortest path problem was first studied by Dubois and Prade [47]. The fuzzy shortest path problem has been solved using different methods recently. [7-12], [14], [16], [17], [19], [20][22], [23-30], [32] Classical Dijkstra algorithm is extended to handle fuzzy number shortest path problem in this work. Part 2 covers fuzzy number and ranking function basics. Part 3 covers Fuzzy Dijkstra algorithm process. Part 4 compares results from two problems. The paper concludes in part 5.

2. Fundamental of Fuzzy Set Theory

The term "fuzzy" was proposed by Zadeh in 1962. In 1965, he published the paper "Fuzzy Sets".

Definition 2.1: (Fuzzy Sets):

Let X is a collections of objects denoted generically by *X*, then a fuzzy set $\underline{A}$ in X is a set of ordered pairs $\underline{A} = \left\{ \left(x, \mu_{\underline{A}}(x) \right) \middle| x \in X, \mu_{\underline{A}}(x) \in [0,1] \right\}$

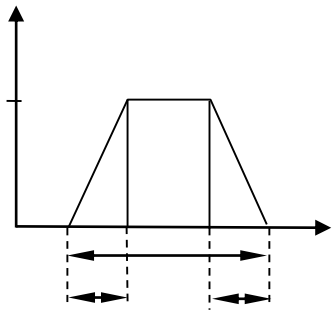

Fig.1 illustrates the support, core, boundary.

Definition 2.2: A fuzzy number $\underline{A} = \{a, b, c, d\}$ is said to be a trapezoidal fuzzy number if its membership function is given by

$$\mu_{\underline{A}}(x) = \begin{cases} \frac{(x-a)}{(b-a)}, & a \le x < b \\ 1, & b \le x \le c \\ \frac{(x-d)}{(c-d)}, & c < x \le d \\ 0, & \text{othersiwe} \end{cases}$$

Arithmetic on Trapezoidal Fuzzy Numbers

Let $\underline{a} = \left(a^L, a^U, \alpha, \beta\right)$ and $\underline{b} = \left(b^L, b^U, \gamma, \delta\right)\left(\frac{\pi}{2} - \theta\right)$ be two trapezoidal fuzzy numbers and $x \in R$. We define

$x > 0, x \in R;\ x\underline{a} = \left(xa^L, xa^U, x\alpha, x\beta\right),$

$x < 0, x \in R;\ x\underline{a} = \left(xa^U, xa^L, -x\beta, -x\alpha\right),$

$\underline{a} + \underline{b} = (a^L + b^L, a^U + b^U, \alpha + \gamma, \beta + \delta),$

$\underline{a} - \underline{b} = (a^L - b^L, a^U - b^U, \alpha + \delta, \beta + \gamma).$

3. Ranking Function

Ranking is an effective fuzzy number ordering strategy. Different ranking functions have been presented to solve linear programming problems with fuzzy parameters. Defining a ranking function helps sort F(R) elements.

Let $\Re : F(R) \to (R)$. We define order on F(R) as follows:

1. $\underline{a} \underset{\Re}{\ge} \underline{b}$ iff $\Re(\underline{a}) \ge \Re(\underline{b})$,
2. $\underline{a} \underset{\Re}{>} \underline{b}$ iff $\Re(\underline{a}) > \Re(\underline{b})$,
3. $\underline{a} \underset{\Re}{=} \underline{b}$ iff $\Re(\underline{a}) = \Re(\underline{b})$
4. $\underline{a} \underset{\Re}{\le} \underline{b}$ iff $\underline{b} \underset{\Re}{\le} \underline{a}$.

Here $\Re$ is the ranking functions, s.t.

$$\Re\left(k\underline{a} + \underline{b}\right) = k\Re(\underline{a}) + \Re\left(\underline{b}\right) \quad (1)$$

$\Re(\underline{a}) = \int_0^1 (\inf \underline{a}_\alpha + \sup \underline{a}_\alpha) d\alpha$ which reduced to

$$\Re(\underline{a}) = \left(a^L + a^U\right) + \frac{1}{2}(\beta - \alpha)$$

For any trapezoidal fuzzy numbers $\underline{a} = \left(a^L, a^U, \alpha, \beta\right)$ and $\underline{b} = (b^L, b^U, \gamma, \delta)$.

We have $\underline{a} \underset{\Re}{\ge} \underline{b}$ if and only if $a^L + a^U + \frac{1}{2}(\beta - \alpha) \ge b^L + b^U + \frac{1}{2}(\delta - \gamma)$ (2)

4. Fuzzy Dijkstra Algorithm

In 1956, Dutch computer scientist Edsger dijkstra invented and published his algorithm in 1959. The shortest path problem is often solved using the Dijksra algorithm. If arc lengths are crisp numbers, Dijkstra algorithm is easy to implement. Here we use conventional Dijksra algorithm to determine FSP & FSD between the source node and all other nodes in the network.

3.1. Algorithm: [42]

Let $\underline{u}_i$ be the fuzzy shortest distance from source node 1 to node i, and define $\underline{d}_{ij}\left(\underset{\Re}{\geq} 0\right)$ as the length of arc (i, j). Then the algorithm defines the label for an immediately succeeding node j as $[\underline{u}_i, i] = \left[\underline{u}_i + \underline{d}_{ij}, i\right], \underline{d}_{ij} \underset{\Re}{\geq} 0.$

The label for the starting node is [(0, 0, 0, 0), -], indicating that the node has no predecessor. Node labels in Dijkstra's algorithm are of two types:

(1) Temporary
(2) Permanent

A temporary label is modified if a shorter route to a node can be found. At the point when no better routes can be found, the status of the temporary label is changed to permanent.

Step 0: Label the source node (node 1) with permanent label [(0, 0, 0, 0), -]. Set i =1.

Step i: (a) Compute the temporary labels $[\underline{u}_i + \underline{d}_{ij}, i]$ for each node j that can be reached from node i, provided j is not permanently labeled. If node j is already labeled with $[\underline{u}_j, k]$ through another node k, and if $\underline{u}_j + \underline{d}_{ij} \underset{\Re}{\leq} \underline{u}_j$ replace $[\underline{u}_j, k]$ with $[\underline{u}_j + \underline{d}_{ij}, i]$.

(b) If all the nodes have permanent labels, stop otherwise, select the label $[\underline{u}_r, s]$ having the fuzzy shortest distance ($\underset{\Re}{=} \underline{u}_r$) among all the temporary labels. (break ties arbitrarily)

Set i = r and repeat step i.

5. Numerical Examples

Example 1: Find FSP from node (1) & destination node (6) (Liu & Kao, 2004).

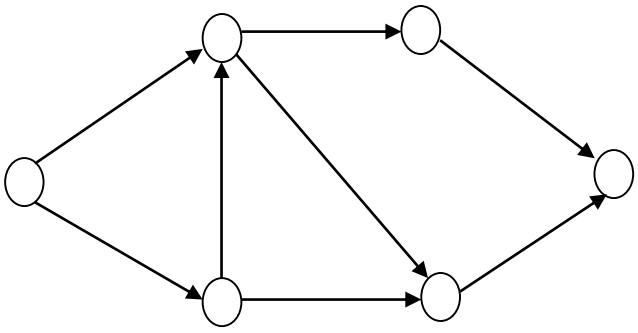

Figure 2. Network of the shortest path (Liu & Kao, 2004)

Solution:

Iteration 0:

Assign the permanent label [(0,0,0,0), -] to node 1.

Iteration 1:

Node	Label	Status
1	[(0, 0, 0,0), -]	Permanent
2	[(10, 20, 20, 30), 1]	Temporary
3	[(52, 62, 65, 70), 1]	Temporary

Iteration 2:

Node	Label	Status
1	[(0, 0, 0,0), -]	Permanent
2	[(10, 20, 20, 30), 1]	Permanent
3	[(45, 58, 60, 75), 2]	Temporary
5	[(62, 75, 80, 95),2]	Temporary

Iteration 3:

Node	Label	Status
1	[(0, 0, 0,0), -]	Permanent
2	[(10, 20, 20, 30), 1]	Permanent
3	[(45, 58, 60, 75), 2]	Permanent
4	[(55, 71, 77, 95),3]	Temporary
5	[(53, 67, 69, 85), 3]	Temporary

Iteration 4:

Node	Label	Status
1	[(0, 0, 0,0), -]	Permanent
2	[(10, 20, 20, 30), 1]	Permanent
3	[(45, 58, 60, 75), 2]	Permanent
4	[(55, 71, 77, 95),3]	Temporary
5	[(53, 67, 69, 85), 3]	Permanent
6	[(103, 137, 149, 185), 5]	Temporary

Iteration 5:

Node	Label	Status
1	[(0, 0, 0,0), -]	Permanent
2	[(10, 20, 20, 30), 1]	Permanent
3	[(45, 58, 60, 75), 2]	Permanent
4	[(55, 71, 77, 95),3]	Permanent
5	[(53, 67, 69, 85), 3]	Permanent
6	[(103, 137, 149, 185), 5]	Temporary

Iteration 6:

Node	Label	Status
1	[(0, 0, 0,0), -]	Permanent
2	[(10, 20, 20, 30), 1]	Permanent
3	[(45, 58, 60, 75), 2]	Permanent
4	[(55, 71, 77, 95),3]	Permanent
5	[(53, 67, 69, 85), 3]	Permanent
6	[(103, 137, 149, 185), 5]	Permanent

Table 1: Different FSP

Node	Fuzzy Distance	Fuzzy shortest path
1	(0, 0, 0,0)	-
2.	(10, 20, 20, 30)	1→2
3	(45, 58, 60, 75)	1→2→3
4	(55, 71, 77, 95)	1→2→3→4
5	(53, 67, 69, 85)	1→2→3→5
6	(103, 137, 149, 185)	1→2→3→5→6

The FSD & FSP from node 1represented in table 1& network figure 3.

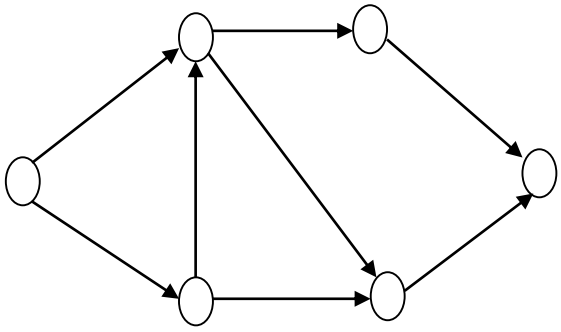

Figure 3. The FSD & FSP from node 1 represented

Example 2: Find FSP from node (1) & destination node (23)

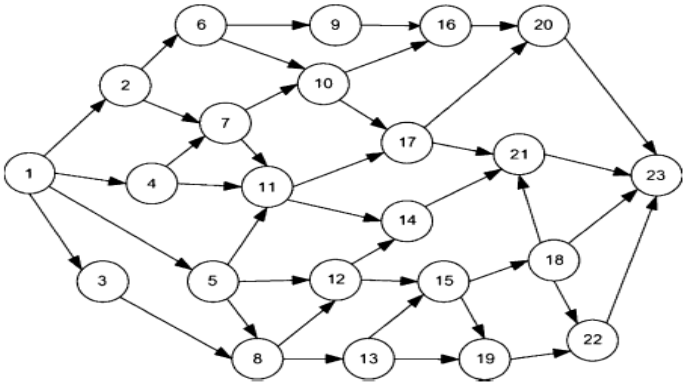

Figure 4: A Transportation Network

Table 2. Fuzzy arc lengths of the Network

Arc	Arc Length	Arc	Arc Length	Arc	Arc Length
[1,2]	[12,13,15,17]	[7,10]	[9,10,12,13]	[15,18]	[8,9,11,13]
[1,3]	[9,11,13,15]	[7,11]	[6,7,8,9]	[15,19]	[5,7,10,12]
[1,4]	[8,10,12,13]	[8,12]	[5,8,9,10]	[16,20]	[9,12,14,16]
[1,5]	[7,8,9,10]	[8,13]	[3,5,8,10]	[17,20]	[7,10,11,12]
[2,6]	[5,10,15,16]	[9,16]	[6,7,9,10]	[17,21]	[6,7,8,10]
[2,7]	[6,11,11,13]	[10,16]	[12,13,16,17]	[18,21]	[15,17,18,19]
[3,8]	[10,11,16,17]	[10,17]	[15,19,20,21]	[18,22]	[3,5,7,9]
[4,7]	[17,20,22,24]	[11,14]	[8,9,11,13]	[18,23]	[5,7,9,11]
[4,11]	[6,10,13,14]	[11,17]	[6,9,11,13]	[19,22]	[15,16,17,19]
[5,8]	[6,9,11,13]	[12,14]	[13,14,16,18]	[20,23]	[13,14,16,17]
[5,11]	[7,10,13,14]	[12,15]	[12,14,15,16]	[21,23]	[12,15,17,18]
[5,12]	[10,13,15,17]	[13,15]	[10,12,14,15]	[22,23]	[4,5,6,8]
[6,9]	[6,8,10,11]	[13,19]	[17,18,19,20]		
[6,10]	[10,11,14,15]	[14,21]	[11,12,13,14]		

Solution:

Iteration 0:

Assign the permanent label [(0, 0, 0, 0), -] to node 1.

Iteration 1:

Nodes 2, 3, 4, 5 can be reached from the last permanently/temporary labeled nodes. Thus the list of labeled nodes temporary and permanent becomes

Node	Label	Status
1	[(0, 0, 0,0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Temporary
3	[(9, 11, 13, 15), 1]	Temporary
4	[(8, 10, 12, 13), 1]	Temporary
5	[(7, 8, 9, 10), 1]	Temporary

Iteration 2

Node	Label	Status
1	[(0, 0, 0,0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Temporary

3	[(9, 11, 13, 15), 1]	Temporary
4	[(8, 10, 12, 13), 1]	Temporary
5	[(7, 8, 9, 10), 1]	Permanent
8	[(13, 17, 20, 23), 5]	Temporary
11	[(14, 18, 22, 24), 5]	Temporary
12	[(17, 21, 24, 27), 5]	Temporary

Iteration 3

Node	Label	Status
1	[(0, 0, 0,0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Temporary
3	[(9, 11, 13, 15), 1]	Temporary
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
7	[(25, 30, 34, 37), 4]	Temporary
8	[(13, 17, 20, 23), 5]	Temporary
11	[(14, 18, 22, 24), 5]	Temporary
12	[(17, 21, 24, 27), 5]	Temporary

Iteration 4:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Temporary
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
7	[(25, 30, 34, 37), 4]	Temporary
8	[(13, 17, 20, 23), 5]	Temporary
11	[(14, 18, 22, 24), 5]	Temporary
12	[(17, 21, 24, 27), 5]	Temporary

Iteration 5:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Temporary
7	[(18, 24, 26, 30), 2]	Temporary
8	[(13, 17, 20, 23), 5]	Temporary
11	[(14, 18, 22, 24), 5]	Temporary
12	[(17, 21, 24, 27), 5]	Temporary

Iteration 6:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Temporary
7	[(18, 24, 26, 30), 2]	Temporary
8	[(13, 17, 20, 23), 5]	Permanent
11	[(14, 18, 22, 24), 5]	Temporary
12	[(17, 21, 24, 27), 5]	Temporary
13	[(16, 22, 28, 33), 8]	Temporary

Iteration 7:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent

5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Temporary
7	[(18, 24, 26, 30), 2]	Temporary
8	[(13, 17, 20, 23), 5]	Permanent
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Temporary
13	[(16, 22, 28, 33), 8]	Temporary
14	[(22, 27, 33, 37), 11]	Temporary
17	[(20, 27, 33, 37), 11]	Temporary

Iteration 8:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Temporary
7	[(18, 24, 26, 30), 2]	Temporary
8	[(13, 17, 20, 23), 5]	Permanent
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Temporary
14	[(22, 27, 33, 37), 11]	Temporary
15	[(26, 34, 42, 48), 13]	Temporary
17	[(20, 27, 33, 37), 11]	Temporary

Iteration 9:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Temporary
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Temporary
10	[(27, 34, 44, 48), 6]	Temporary
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Temporary
14	[(22, 27, 33, 37), 11]	Temporary
15	[(26, 34, 42, 48), 13]	Temporary
17	[(20, 27, 33, 37), 11]	Temporary

Iteration 10:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Temporary
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Temporary
10	[(27, 34, 44, 48), 6]	Temporary
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Temporary
15	[(26, 34, 42, 48), 13]	Temporary

17	[(20, 27, 33, 37), 11]	Temporary
19	[(33, 40, 47, 53), 13]	Temporary

Iteration 11

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Permanent
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Temporary
10	[(27, 34, 44, 48), 6]	Temporary
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Temporary
15	[(26, 34, 42, 48), 13]	Temporary
17	[(20, 27, 33, 37), 11]	Temporary
19	[(33, 40, 47, 53), 13]	Temporary

Iteration 12:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Permanent
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Temporary
10	[(27, 34, 44, 48), 6]	Temporary
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Temporary
15	[(26, 34, 42, 48), 13]	Temporary
17	[(20, 27, 33, 37), 11]	Permanent
19	[(33, 40, 47, 53), 13]	Temporary
20	[(27, 37, 44, 49), 17]	Temporary
21	[(26, 34, 41, 47), 17]	Temporary

Iteration 13:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Permanent
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Temporary
10	[(27, 34, 44, 48), 6]	Temporary
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Permanent
15	[(26, 34, 42, 48), 13]	Temporary
17	[(20, 27, 33, 37), 11]	Permanent

19	[(33, 40, 47, 53), 13]	Temporary
20	[(27, 37, 44, 49), 17]	Temporary
21	[(26, 34, 41, 47), 17]	Temporary

Iteration 14:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Permanent
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Permanent
10	[(27, 34, 44, 48), 6]	Temporary
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Permanent
15	[(26, 34, 42, 48), 13]	Temporary
16	[(29, 38, 49, 54), 9]	Temporary
17	[(20, 27, 33, 37), 11]	Permanent
19	[(33, 40, 47, 53), 13]	Temporary
20	[(27, 37, 44, 49), 17]	Temporary
21	[(26, 34, 41, 47), 17]	Temporary

Iteration 15:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Permanent
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Permanent
10	[(27, 34, 44, 48), 6]	Permanent
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Permanent
15	[(26, 34, 42, 48), 13]	Temporary
16	[(29, 38, 49, 54), 9]	Temporary
17	[(20, 27, 33, 37), 11]	Permanent
19	[(33, 40, 47, 53), 13]	Temporary
20	[(27, 37, 44, 49), 17]	Temporary
21	[(26, 34, 41, 47), 17]	Temporary

Iteration 16:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Permanent
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Permanent
10	[(27, 34, 44, 48), 6]	Permanent
11	[(14, 18, 22, 24), 5]	Permanent

12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Permanent
15	[(26, 34, 42, 48), 13]	Temporary
16	[(29, 38, 49, 54), 9]	Temporary
17	[(20, 27, 33, 37), 11]	Permanent
18	[(34, 43, 53, 61), 15]	Temporary
19	[(33, 40, 47, 53), 13]	Temporary
20	[(27, 37, 44, 49), 17]	Temporary
21	[(26, 34, 41, 47), 17]	Permanent

Iteration 17:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Permanent
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Permanent
10	[(27, 34, 44, 48), 6]	Permanent
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Permanent
15	[(26, 34, 42, 48), 13]	Permanent
16	[(29, 38, 49, 54), 9]	Temporary
17	[(20, 27, 33, 37), 11]	Permanent
18	[(34, 43, 53, 61), 15]	Temporary
19	[(33, 40, 47, 53), 13]	Temporary
20	[(27, 37, 44, 49), 17]	Temporary
21	[(26, 34, 41, 47), 17]	Permanent
23	[(38, 49, 58, 65), 21]	Temporary

Iteration 18:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Permanent
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Permanent
10	[(27, 34, 44, 48), 6]	Permanent
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Permanent
15	[(26, 34, 42, 48), 13]	Permanent
16	[(29, 38, 49, 54), 9]	Temporary
17	[(20, 27, 33, 37), 11]	Permanent
18	[(34, 43, 53, 61), 15]	Temporary
19	[(33, 40, 47, 53), 13]	Temporary
20	[(27, 37, 44, 49), 17]	Permanent
21	[(26, 34, 41, 47), 17]	Permanent
23	[(38, 49, 58, 65), 21]	Temporary

Iteration 19:

Node	Label	Status

1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Permanent
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Permanent
10	[(27, 34, 44, 48), 6]	Permanent
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Permanent
15	[(26, 34, 42, 48), 13]	Permanent
16	[(29, 38, 49, 54), 9]	Permanent
17	[(20, 27, 33, 37), 11]	Permanent
18	[(34, 43, 53, 61), 15]	Temporary
19	[(33, 40, 47, 53), 13]	Temporary
20	[(27, 37, 44, 49), 17]	Permanent
21	[(26, 34, 41, 47), 17]	Permanent
23	[(38, 49, 58, 65), 21]	Temporary

Iteration 20:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Permanent
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Permanent
10	[(27, 34, 44, 48), 6]	Permanent
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Permanent
15	[(26, 34, 42, 48), 13]	Permanent
16	[(29, 38, 49, 54), 9]	Permanent
17	[(20, 27, 33, 37), 11]	Permanent
18	[(34, 43, 53, 61), 15]	Temporary
19	[(33, 40, 47, 53), 13]	Permanent
20	[(27, 37, 44, 49), 17]	Permanent
21	[(26, 34, 41, 47), 17]	Permanent
22	[(48, 56, 64, 72), 19]	Temporary
23	[(38, 49, 58, 65), 21]	Temporary

Iteration 21:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Permanent
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Permanent
10	[(27, 34, 44, 48), 6]	Permanent
11	[(14, 18, 22, 24), 5]	Permanent

12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Permanent
15	[(26, 34, 42, 48), 13]	Permanent
16	[(29, 38, 49, 54), 9]	Permanent
17	[(20, 27, 33, 37), 11]	Permanent
18	[(34, 43, 53, 61), 15]	Permanent
19	[(33, 40, 47, 53), 13]	Permanent
20	[(27, 37, 44, 49), 17]	Permanent
21	[(26, 34, 41, 47), 17]	Permanent
22	[(37, 48, 60, 70), 18]	Temporary
23	[(38, 49, 58, 65), 21]	Temporary

Iteration 22:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Permanent
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Permanent
10	[(27, 34, 44, 48), 6]	Permanent
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Permanent
15	[(26, 34, 42, 48), 13]	Permanent
16	[(29, 38, 49, 54), 9]	Permanent
17	[(20, 27, 33, 37), 11]	Permanent
18	[(34, 43, 53, 61), 15]	Permanent
19	[(33, 40, 47, 53), 13]	Permanent
20	[(27, 37, 44, 49), 17]	Permanent
21	[(26, 34, 41, 47), 17]	Permanent
22	[(37, 48, 60, 70), 18]	Temporary
23	[(38, 49, 58, 65), 21]	Permanent

Iteration 23:

Node	Label	Status
1	[(0, 0, 0, 0), -]	Permanent
2	[(12, 13, 15, 17), 1]	Permanent
3	[(9, 11, 13, 15), 1]	Permanent
4	[(8, 10, 12, 13), 1]	Permanent
5	[(7, 8, 9, 10), 1]	Permanent
6	[(17, 23, 30, 33), 2]	Permanent
7	[(18, 24, 26, 30), 2]	Permanent
8	[(13, 17, 20, 23), 5]	Permanent
9	[(23, 31, 40, 44), 6]	Permanent
10	[(27, 34, 44, 48), 6]	Permanent
11	[(14, 18, 22, 24), 5]	Permanent
12	[(17, 21, 24, 27), 5]	Permanent
13	[(16, 22, 28, 33), 8]	Permanent
14	[(22, 27, 33, 37), 11]	Permanent
15	[(26, 34, 42, 48), 13]	Permanent
16	[(29, 38, 49, 54), 9]	Permanent
17	[(20, 27, 33, 37), 11]	Permanent
18	[(34, 43, 53, 61), 15]	Permanent
19	[(33, 40, 47, 53), 13]	Permanent
20	[(27, 37, 44, 49), 17]	Permanent
21	[(26, 34, 41, 47), 17]	Permanent

22	[(37, 48, 60, 70), 18]	permanent
23	[(38, 49, 58, 65), 21]	Permanent

Table 3: Tabular representation of FSD & FSP

Node	Fuzzy Distance	Fuzzy shortest path
1	(0, 0, 0,0)	-
2	[(12, 13, 15, 17)	1→2
3	(9, 11, 13, 15)	1→3
4	(8, 10, 12, 13)	1→4
5	(7, 8, 9, 10)	1→5
6	(17, 23, 30, 33)	1→2→6
7	(18, 24, 26, 30)	1→2→7
8	(13, 17, 20, 23)	1→5→8
9	(23, 31, 40, 44)	1→2→6→9
10	(27, 34, 44, 48)	1→2→6→10
11	(14, 18, 22, 24)	1→5→11
12	(17, 21, 24, 27)	1→5→12
13	(16, 22, 28, 33)	1→5→8→13
14	(22, 27, 33, 37)	1→5→11→14
15	(26, 34, 42, 48)	1→5→8→13→15
16	(29, 38, 49, 54)	1→2→6→9→16
17	(20, 27, 33, 37)	1→5→11→17
18	(34, 43, 53, 61)	1→5→8→13→15→18
19	(33, 40, 47, 53)	1→5→8→13→19
20	(27, 37, 44, 49)	1→5→11→17→20
21	(26, 34, 41, 47)	1→5→11→17→21
22	(37, 48, 60, 70)	1→5→8→13→15→18→22
23	(38, 49, 58, 65)	1→5→11→17→21→23

6. Result and Discussion

Applying the fuzzy Dijkstra's algorithm on the network of Example 1, the obtained FSP & FSD between node 1 and node 6 are 1→2→3→5→6 and (103,137, 149, 185) respectively. Which is the same result as obtained by Liu & Kao, 2004. Similarly applying fuzzy Dijkstra's algorithm on the network of Example 2, the obtained FSP & FSD between node 1 and node 23 are 1→5→11→17→21→23 and (38, 49, 58, 65) respectively. Which is the same result as obtained in reference [6, 16].

Advantages of the Proposed Algorithm

1. To find FSP & FSD repeated application of algorithm is not required.
2. Knowledge of fuzzy arithmetic and ranking function is required.
3. The use of linear programming technique is not required.
4. The goal and parametric programming technique is not required.
5. The proposed algorithm can be programmed.

7. Conclusion

The shortest path problem with fuzzy arc lengths is solved by extending Dijkstra's algorithm. Transportation systems, logistics management, and other network optimization problems that may be phrased as shortest path problems can use fuzzy Dijkstra's algorithm.

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Performance analysis of Support Vector Machine and Reduced Support Vector Machine

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Abstract

Recently, there has been significant interest in utilizing Support Vector Machines (SVMs) to achieve high-performance pattern classification. In cases where data is linearly separable, SVMs aim to position a class boundary so that the margin from the nearest data points is maximized. This objective is achieved by solving a Quadratic Programming (QP) problem, where the resulting class boundary is represented as a linear combination of a subset of the training data, known as the support vectors. For scenarios where the data is not linearly separable, SVMs employ a transformation into a higher-dimensional space. A similar QP problem can be formulated and solved in this transformed space, with dot products in the higher-dimensional space being computed using kernel functions applied in the input space. The elegance of this QP formulation, combined with the connection between complexity control and Vapnik-Chervonenkis dimensions, is a key reason why the SVM method is highly regarded. Another concept related to high-performance pattern classification is boosting multiple classifiers, whose effectiveness is often attributed to the margin between data points and class boundaries. The Reduced Support Vector Machine (RSVM) was created to handle large datasets more efficiently by reducing computational costs and simplifying the model. This paper explores RSVM by looking at how samples are selected, how reliable the method is, and the properties of the reduced kernel. In RSVM, the decision boundary is modeled as a combination of kernels. Instead of using the full set of data, RSVM works with a smaller, selected subset of kernels taken from a larger candidate set.

Keywords: Support Vector Machine, Reduced Support Vector Machine, Quadratic Support, programming, Kernel Function

1. Introduction

Boser, Guyon, and Vapnik first presented Support Vector Machines (SVMs) at COLT-92 in 1992. SVMs are supervised learning methods for applications involving regression and classification. They are part of the generalized linear classifier family and are made to strike a balance between preventing overfitting and making accurate predictions. In order to determine the optimal decision boundary, SVMs map data into a high-dimensional feature space and apply optimization strategies informed by statistical learning theory. SVMs, which were first well-liked in the NIPS community, were well-known for their ability to perform as well as more sophisticated neural networks while obtaining high accuracy in handwriting recognition tests utilizing basic pixel data. Today, SVMs are widely used in various applications, including pattern recognition, face and handwriting analysis, and regression tasks. Developed by Vapnik, SVMs have become well-known for their strong empirical performance and versatility in handling complex problems.

The Empirical Risk Minimization (ERM) principle, which focuses on minimizing errors on the training data, is used by traditional neural networks. Support Vector Machines (SVMs) employ Structural Risk Minimization (SRM), on the other hand, to improve generalization to new data by minimizing the upper bound of prediction errors. This distinction aids SVMs in accomplishing the objective of statistical learning, which is to perform well on unknown data. SVMs were first developed to solve classification difficulties, but they have since been modified to solve regression problems as well.

- Support Vector Machines (SVMs) are supervised learning methods used for classification tasks.
- SVMs work by creating a separating hyperplane that maximizes the margin between two groups of data points.
- To calculate this margin, two parallel hyperplanes are placed on either side of the separating hyperplane, close to the two data groups.
- A common goal in machine learning is classifying data, where the aim is to predict the class of a new data point based on known data points belonging to two classes.
- In SVMs, data points are represented as vectors in a p-dimensional space (a list of p numbers). The goal is to determine if a (p – 1)-dimensional hyperplane can separate these data points into distinct classes, which defines a linear classifier.

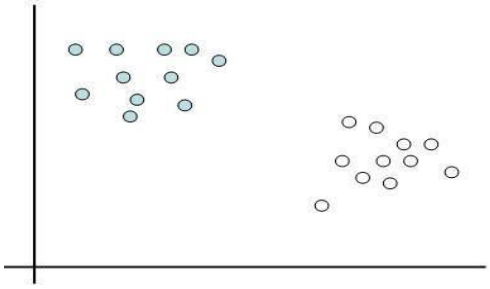

Fig.1 Classified data set

This dataset appears to be linearly separable, meaning we can divide the two classes with a straight line, as shown by the two colors. Since the data points exist in two dimensions, we refer to this divider as a straight line. Extending to higher dimensions is similar: in three dimensions, we'd use a plane, and in higher dimensions, we'd use a hyperplane.

However, even though we can draw a straight line to separate the classes, there's a challenge: there are infinitely many possible lines. So, how do we choose the best one?

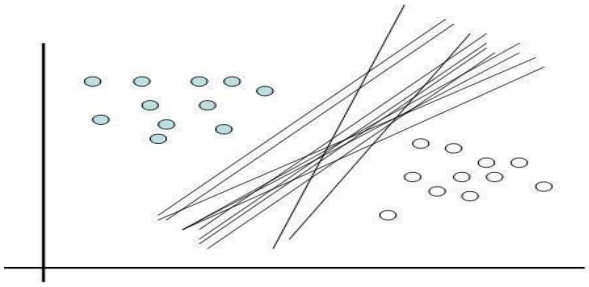

Fig.2 Optimal hyperplane

i. Confidence in making the correct prediction:

Without going into too much detail, the functional margin formalizes this intuition because the purpose of this piece is to understand why support vector machines are called that rather than what they are. The functional margin of a hyperplane given by $wx + b = 0$ w.r.t a specific training example $(x^{(i)}, y^{(i)})$ is defined as:

$$\hat{\gamma}^{(i)} = y^{(i)}(w^T x^{(i)} + b)$$

If$y^{(i)} = 1$, for a large functional margin (greater confidence in correct prediction) we want $w^T x^{(i)} + b \gg 0$

If$y^{(i)} = -1$,for a large functional margin we want $w^T x^{(i)} + b \ll 0$.

Theabovecapturesourfirstintuitionintoasingleformalstatementthatwewould like the functional margin to be large.

ii. Margin:

Selecting the hyperplane with the greatest distance from the training points is another instinct for selecting the optimal one. The geometric margin formalizes this. The geometric margin, without going into the specifics of the derivation, is provided by:

$$\gamma^{(i)} = \frac{\hat{\gamma}^{(i)}}{||w||}$$

which is just the normalized functional margin. These ideas therefore result in the maximum margin classifier, which is an SVM forerunner. In conclusion, the optimization task is to implement these intuitions and obtain the optimal hyperplane.

:

Choose γ, w, b so as to maximize the geometric margin.

$$max_{\gamma,w,b}\gamma$$

Subject to the condition that $y^{(i)}(w^T x^{(i)} + b) > \gamma$ and $\|w\| = 1$.

Support Vector Machines are the result of attempting to formulate the aforementioned optimization problem as a convex optimization problem.

The data I looked at was also linearly separable. The concept is easily transferable to non-separable data. For non-separable data, the dual of the support vector machines in the general case is as follows:

$$maxL_D = \sum_i \alpha_i - \frac{1}{2}\sum_{i,j} \alpha_i \alpha_j y_i y_j \langle x_i \cdot x_j \rangle$$

Subject to:

$$0 \leq \alpha_i \leq C$$

$$\sum_i \alpha_i y_i = 0$$

The solution is given by:

$$w = \sum_{i=1}^{N_S} \alpha_i y_i x_i \qquad (1)$$

Where N_S is the number of support vectors and α represent the Lagrangian multipliers.

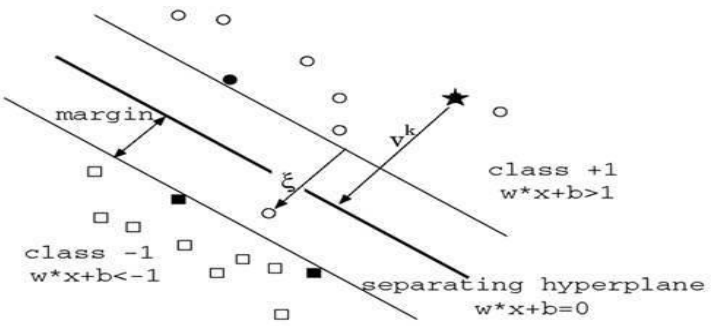

Fig-3: Hyperplane with margin

2. Support Vectors

In the picture above, the classifier's distance from the nearest data points, known as the support vectors (darkened data points), is indicated by the thinner lines. The margin is the separation of the two thin lines. It is the Support Vectors that limit the margin's width. Although we won't get into that, they give us a lot of benefits because they make up a relatively small portion of the entire number of data points.

To understand this, consider a mechanical analogy. Consider that the data is in $\mathcal{R}^2$and suppose the i^{ith}support vector exerts a force of $F_i = \alpha_i y_i \hat{w}$on a stiff sheet lying along the decision surface.$\hat{w}$represents the unit vector in the direction$w$.

a. The support vectors are the most significant data points since they have the highest values. The decision sheet is most strongly impacted by these points. Any point in the non-separable situation must have this force applied below C.

b. Since the torque exerted by the support vectors comes out to be zero, **we can say that these specific data points are "supporting" the hyperplane into "equilibrium"**.

3. What are Support Vector Machine sized for?

The Reduced Support Vector Machine (RSVM), an alternative to the traditional SVM, was proposed. In order to solve a smaller optimization problem and preselect a portion of data as support vectors, SVM with nonlinear kernels was developed in response to the need to overcome the challenge of handling enormous data sets.

The reduced support vector machine, or RSVM, was developed with the practical goals of reducing model complexity and eliminating certain computing difficulties when working with big data sets. We examine the RSVM's robustness, reduced kernel spectral analysis, and sample design. A mix of kernels is the nonlinear separation surface that we consider. The RSVM uses kernels chosen from a specific candidate set in a reduced mixture rather than a full model.

The spectral analysis of the reduced kernel and the strength of the random subset mixing model are the two main concepts that are the focus of the key discoveries. Three factors are used to assess robustness:

1. To what extent does the model differ?

2. The bias or distinction between the complete and reduced models.
3. The capacity to differentiate, during testing, between the reduced and full models. We compare the eigenstructures of the entire kernel matrix with the approximation kernel matrix (made with random subsets) in the spectral analysis. The slight variations demonstrate that the majority of the crucial data required for learning tasks is retained by the approximation kernels.

Additionally, we examine a few statistical ideas that are associated with the reduced set technique, specifically as they pertain to RSVM. This strategy isn't exclusive to

Here we outline the key modifications from standard SVM to RSVM. The main characteristic of RSVM is to reduce the matrix Q from $l \times l$ to $l \times m$, where m is the size of a randomly selected subset of training data considered.

Given a training set$\{(x_i,y_i), x_i \in R^n, y_i \in \{-1,1\}, i=1,2,\cdots,l\}$,the SVM solves the following optimization problem: Such that

$$\min_{w,\in,b} \frac{1}{2} w^T w + C\left(\sum_{i-1}^{i} \in_i^2\right)$$

$$y_i\left(w^T \varphi(x_i) + b\right) >= 1 - \in_i$$

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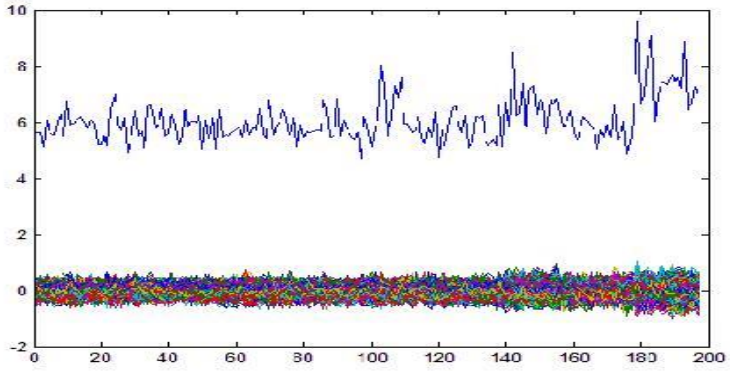

Fig.4 *Analysis by svm, margin width is more*

Where $\varphi(x)$maps x into a higher dimensional space.
Itsdualformbecomesasimplerboundconstrainedproblemwiththenumberof variables equal to l:

$$\min \frac{1}{2}\sigma^T (Q + \frac{I}{2C})\sigma - e^T \sigma$$

Such that $0 \le \sigma_i, i = 1, 2.....i$

Where e is the vector of all ones, Q, $Q_{ij}=y_i y_j K(x_i, x_j)$ We consider a simpler form

$$\min \frac{1}{2}\sigma^{\sim T}\sigma +$$

$$\sigma b, \in$$

$$Q\sigma >= e - \in$$

Solve
$\omega^T\varphi(x_i)+b^*=0$ where

$$w = \sum_{i \in R} y_i \sigma_i \varphi(x_i)$$

4. Comparative Study of SVM And RSVM for Cancer Data Set

The following figures show the comparative study of support vector machines and reduced support vector machines.SVM requires a large margin width, whereas RSVM requires a small margin width.

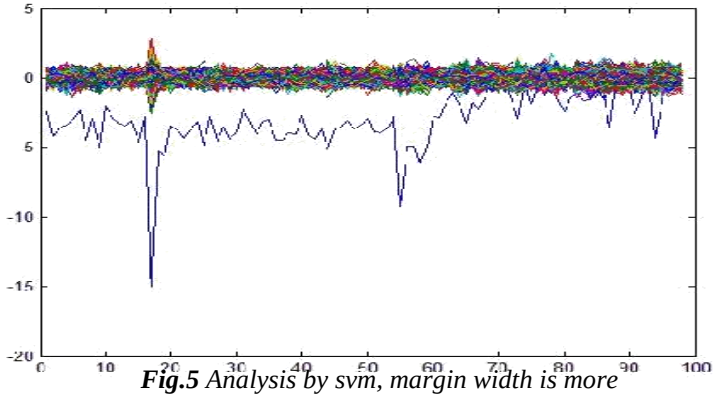

Fig.5 *Analysis by svm, margin width is more*

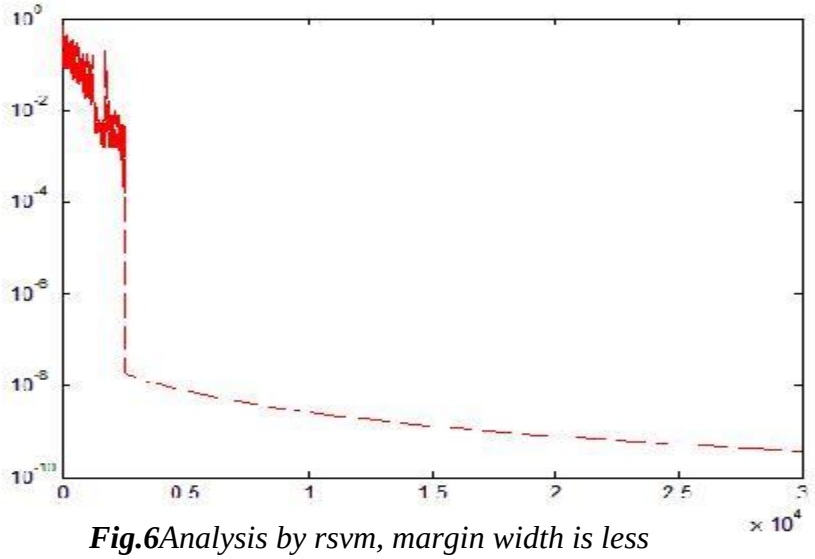

Fig.6*Analysis by rsvm, margin width is less*

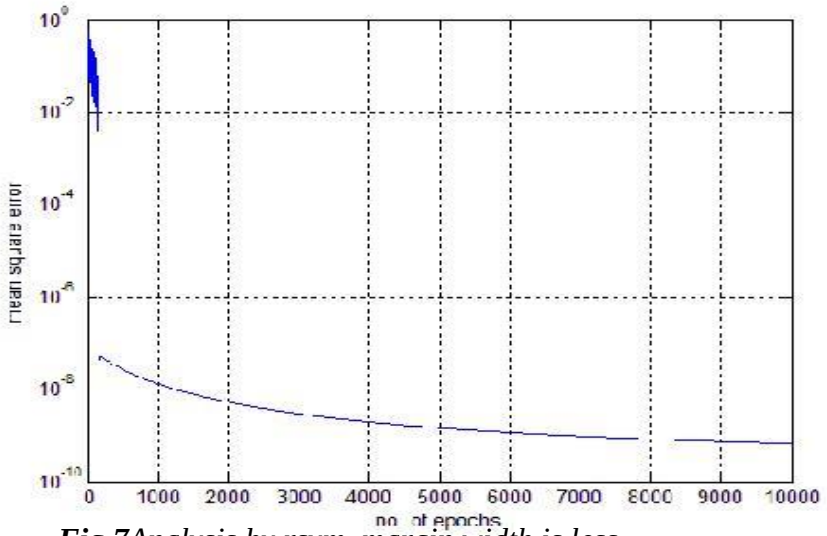

Fig*.7Analysis by rsvm, margin width is less*

3. SVM Application

SVM has been effective in a variety of real-world issues.

Classification of images and text (including hypertext)

• Bioinformatics, which includes the classification of proteins and cancer.

4. Weakness of SVM

• Noise sensitivity affects it.

Even a small number of incorrectly classified instances can significantly impair performance.

•It only considers two classes.

•How to do multi class classification with SVM?

5. Advantages of RSVM

- RSVM: An effective classifier for large datasets
- Classifieruses10%orlessofdataset
- Can handle massive data sets
- Much faster than other algorithms

- Test set correctness
- Same or better than full data set
- Much better than randomly chosen subset

6. Conclusion

Support Vector Machines (SVMs), which combine methods for handling high-dimensional data with generalization control, are a potent approach to data modelling. They effectively use interior point methods to solve a global quadratic optimization problem with box constraints. A universal foundation for comparing model architectures is provided by kernel mapping. SVMs minimize the weight vector in classification in order to maximize the margin, producing sparse support vectors that sit on the boundary and condense important information for data separation.

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Derivation of The Base Current in Lightning Channels from Remote Electromagnetic Fields, Considering Inclined Channel Geometry

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Abstract

The sloped position of a flash of lightning return-stroke channel has a major effect on the accompanying electromagnetic field's waveform. This paper offers methods for determining the greatest point and wave shape of lightening stroke of return power at the base of a sloped lightning channel using electromagnetic field oscillations observed tens of kilometers away. Three stroke of return models are taken into account, including the transmission line (TL), the updated TL design that includes exponentially current decline height (MTLE), as well as the altered TL structure drop in height with a straight current (MTLL). The base-current-channel increase is calculated analytically using the observed electric or magnetic field's peak and the movement of the field of radiation elements for sloped channels.

Furthermore, the wave of current form located at the channel's base has been restored. using the relationship between the sum of the induction with field of radiation elements as well as the measured electromagnetic radiation waveform and the base-current-channel. The proposed expressions demonstrate accurate estimate of the peak and wave shape of the channel based energy for inclined channels. Inverse problem of determining lightning source variables from electromagnetic fields for sloped channels is being tackled for the first time in this work. The findings lay the groundwork for improving remote lightning current measuring methods, which are essential for comprehending and reducing lightning-related risks.

Keywords: Lightning stroke of return; Lighting current; Electromagnetic field waveforms; Lightning channel at an incline; Inverse problem

1. Introduction

Electromagnetic fields are naturally produced by the movement of charges of electricity during lightning discharge events. Researchers can determine lightning parameters including current, transfer of charge, and loss of energy by measuring these fields. Comprehending these variables is essential for furthering lightning physics research, enhancing safety protocols, and reducing lightning-related hazards. Measurements of electromagnetic fields have been widely employed in studies to calculate return-stroke currents, which are essential for understanding lightning activity. Modern techniques to lightning analysis have their roots in the early work of scholars like Uman and McLain (1970) and Norinder and Dahle (1945). Remote observations of lightning's magnetic and field of electricity are the primary method used to capture the radiation component of the electromagnetic spectrum. These measures are a useful substitute for DC evaluations, which are more accurate but necessitate towering buildings that may affect the lightning process naturally. On the other hand, distant field measurements make it easier to collect information about lightning incidents that happen naturally, enabling researchers to rapidly compile large datasets. In large-scale research when direct measurements are impractical, this method is especially helpful.

Researchers use engineering models of lightning stroke of return s, which relate measured electromagnetic fields to base-current-channel, to understand remote field observations. These models are useful for examining the waveforms and values of lightning currents, despite the fact that they include approximations and errors. Rachidi & Thottappillil (1993) reviewed a number of return-stroke models, highlighting their advantages and disadvantages in terms of simulating lightning properties.

One of the pioneering models by Bruce and Golde (1941) suggested that the channel-base wave of current form could be obtained by integrating the far-field radiation element over time. Although groundbreaking, this model struggled to indicate complicated waveform attributes. Subsequent models, like the transmission-line (TL) model presented by Uman and McLain (1969), offered a more direct correlation among the base-current-channel and the far-field waveform. This eliminated relationship confirmed advantageous for understanding lightning stroke of return s.

Nucci et al. (1988) developed an improved TL structure that includes exponential current degradation with height (MTLE), which further advanced lightning modeling. Waveform accuracy was increased by this model's incorporation of spatial current changes along the lightning route. Heidler's (1985) introduction of the traveling-current-source model was another noteworthy contribution. This model depicted the base-current-channel as a sequence of the distant field. Time shifted components. Additionally, the Diendorfer-Uman (DU) approach used the distant field. components as well as its time derivative to restore the base-current-channel.

The majority of models mainly deal with vertically oriented lightning channels, despite their achievements. However, because to things like wind or unusual impact spots, natural lightning often involves slanted channels. Because the geometry affects the components of the radiation and induction fields, inclination complicates the correlations among electromagnetic fields and base-current-channel.
In order to overcome these difficulties, recent studies have extended current models to take sloped channels into consideration. In order to predict the channel-base current's peak and

waveform while accounting for inclination effects, mathematical formulae have been developed. Well-known models such as the MTLE structure, the TL structure and the MTLL structure (a variation with linear current deterioration with height) are used in these formulations. This method makes it possible to analyze the electromagnetic fields produced by sloped lightning channels with greater accuracy.

One significant development is the reconstruction of waveforms and the assessment of channel-base highest currents from handset the electromagnetic spectrum field data. These developments have a wide range of uses, such as strengthening thunderstorm research, developing efficient lightning protection systems, and boosting lightning detecting networks. Researchers can enhance remote monitoring techniques and gain a deeper understanding of the intricate dynamics of natural lightning by including channel inclination into analytical frameworks. Addressing lightning-related issues and developing the field of atmosphere-generated electricity depend on this advancement.

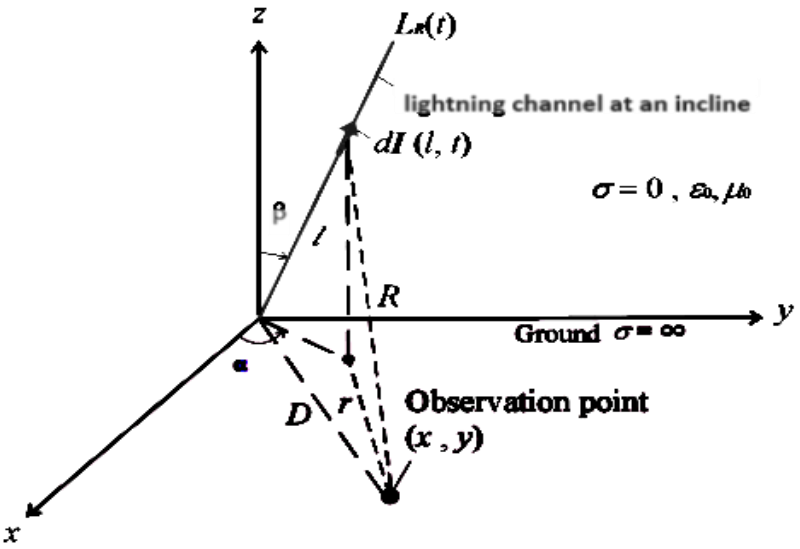


Fig. 1. The structure of channel of the lightning at an incline and the determination of observation point location over a perfectly conducting surface are essential for accurate analysis.

2. Comprehensive formulation

El Dein et al. (2014) and Abouzeid et al. (2015) derived the vertical field of electricityE_z at a location point (x, y) on a completely conducting ground, caused by a wave of current I traveling along a sloped lightning channel, as shown in Fig. 1. This field is stated as follows:

$$E_z(x,y,t) = E_{zs} + E_{zi} + E_{zr}$$

$$= \int_0^{L_R(t)} C_{ezs}(l) \int_0^t I(l, \tau - R/c) d\tau dl + \int_0^{L_R(t)} C_{ezi}(l) I(l, \tau - \frac{R}{c}) dl - \int_0^{L_R(t)} C_{ezr}(l) \frac{\partial I(l, t - \frac{R}{c})}{\partial t} dl \qquad (1)$$

Where,

$$C_{ezs}(l) = \frac{(3z'^2 - R^2)\cos\beta - 3z'\sin\beta[(x - x')\cos\alpha + (y - y')\sin\alpha]}{2\pi\varepsilon_0 R^5}$$

$$C_{ezi}(l) = \frac{(3z'^2 - R^2)\cos\beta - 3z'\sin\beta[(x - x')\cos\alpha + (y - y')\sin\alpha]}{2\pi\varepsilon_0 cR^4}$$

$$C_{ezr}(l) = \frac{z'\sin\beta[((x - x')\cos\alpha + (y - y')\sin\alpha)] + r^2\cos\beta}{2\pi\varepsilon_0 c^2 R^3}$$

$$l = \sqrt{x'^2 + y'^2 + z'^2} \tag{2}$$

$$R = \sqrt{(x - x')^2 + (y - y')^2 + z^2}$$

$$= \sqrt{(x - l\sin\beta\cos\alpha)^2 + (y - l\sin\beta\sin\alpha)^2 + (l\cos\beta)^2}$$

$$= \sqrt{x^2 + y^2 - 2xl\sin\beta\cos\alpha - 2yl\sin\alpha\sin\beta + l^2}$$

$$= \sqrt{x^2 + y^2 - 2l\sin\beta(x\cos\alpha + y\sin\alpha) + l^2}$$

$$= \sqrt{D^2 - 2l\sin\beta(x\cos\alpha + y\sin\alpha) + l^2}$$

$$D = \sqrt{x^2 + y^2}$$

$$R = \sqrt{(x - x')^2 + (y - y')^2}$$

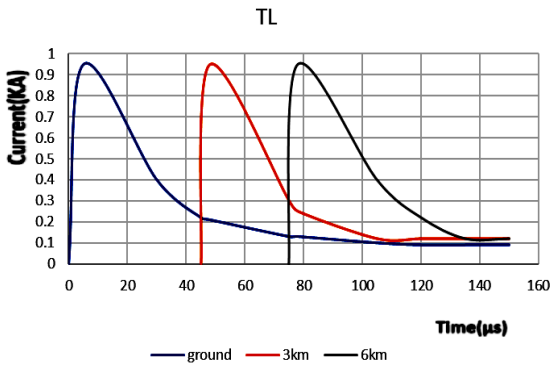
Here v = velocity at which the electrical current moves across the inclined channel, c = the velocity of light, and ε_0 = vacuum permittivity. The angle of the lightening channel is β w.r.t the z-axis& α w.r.t the x-axis. The point of the infinitesimal current item dI is (x', y', z'). The lightning channel segment where current sources completely contribute to an electromagnetic energy at the observational point site at time(t) is represented by the emission channel length, LR(t). The expression t equals LR(t)/v + R(LR(t))/c can be solved to get this duration. Different components of the field of electricity the radiation element Ezr, the induction element Ezi, & the electrostatic element Ezsare represented by the context in Equation (1). It displays the channel's radiating length and its relationship to the total field calculation.

They establish the connection between the current flowing across the channel at a precise distance l and time t and the beginning current at $l = 0$.

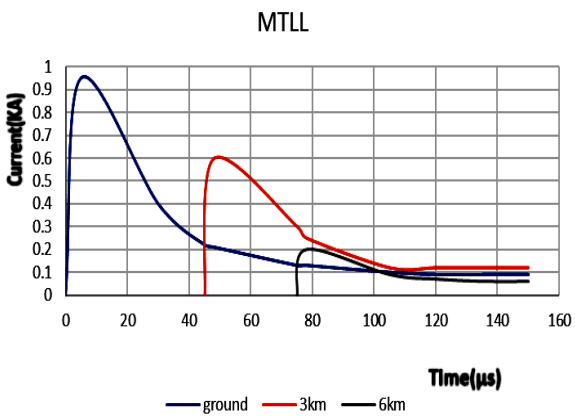
$$I(l, t) = I(0, t - l/v) \tag{3}$$

$$I(l, t) = (1 - l/L)I(0, t - l/v) \tag{4}$$

In this case, L stands for the lightning channel's overall length, and λ is represented by MTLE model's constant of current decay.



(a)



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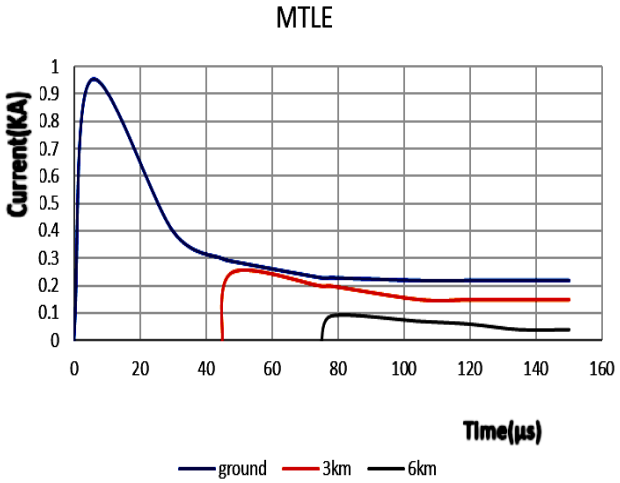


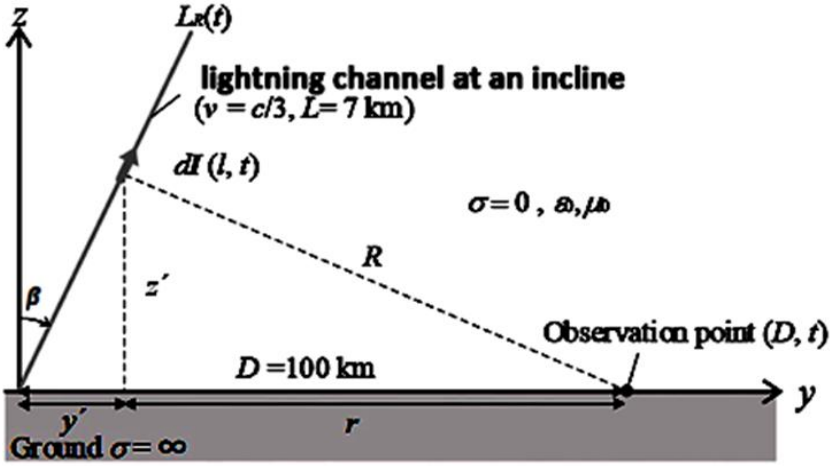
(c)

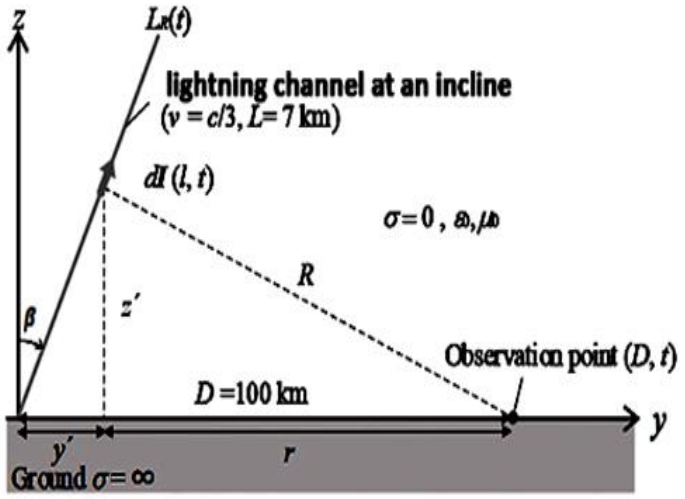
Figure 2. displays the lightning waveforms of current at three sites along the medium: lowest point (l=0), 3 km, & 6 km. Assuming L=7km, λ=2km, and v=c/3, these waveforms are computed utilizing the TL (in Eq. 3), MTLL (in Eq. 4), & MTLE (Eq. 5) models.

The electrical waveform of current at l=0 (base), 3 km, and 6 km along a channel are evaluated using the TL, MTLL, & MTLE structures. According to the MTLE model, current transmission speed is v=c/3, and the channel's length in total remains unchanged at L=7km, & the decline constant is λ=2km.

$$I(t) = I_0 \frac{\left(\frac{t}{\tau_1}\right)^6}{1+\left(\frac{t}{\tau_1}\right)^6} \exp(-t/\tau_2) \qquad (6)$$

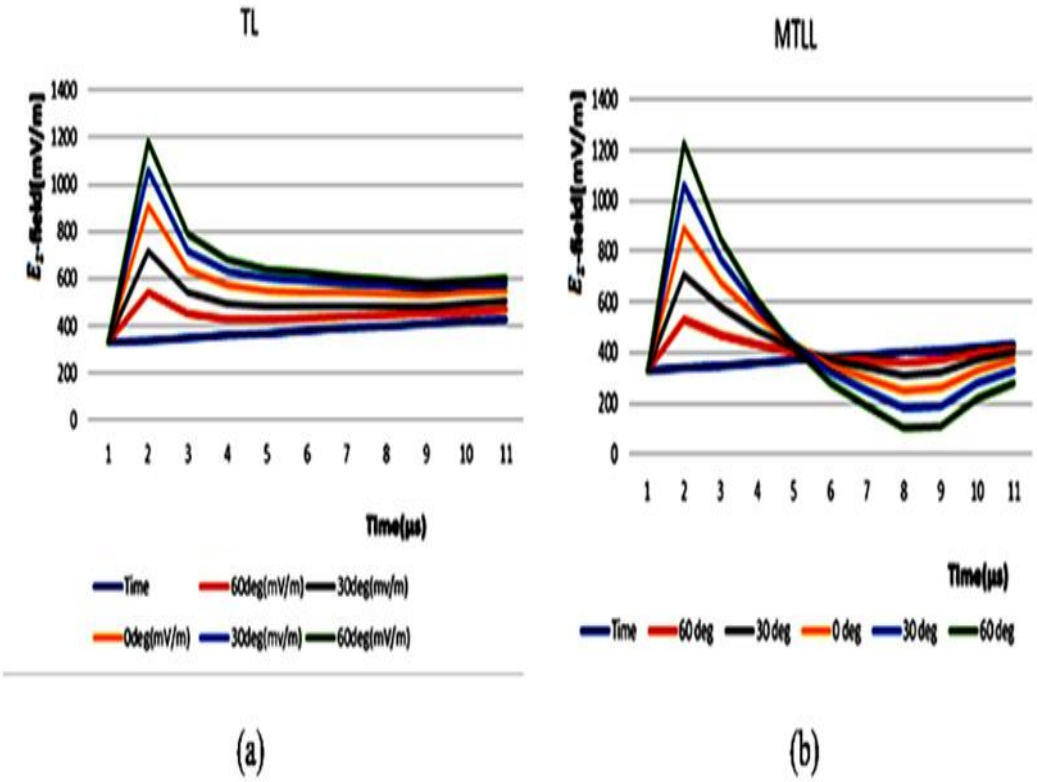
With I_0=1.1kA, τ_1=1.5μs, & τ_2=38μs as the parameters, the peak current is 1kA. The waveform has a half-peak period of 30 μs and a rising time of 1 μs.





2.1 Model setup and configuration

On the y-z plane, where α=90°, Figure 3 displays the observation point & the sloping lightning channel (refer to Figure 1). A inclination towards the observation point is indicated by a positive value for the angle β, which represents the channel's inclination from the z-axis and runs from -60° to +60°. The base of the channel and the observation spot are 100 kilometres apart, or D=100.



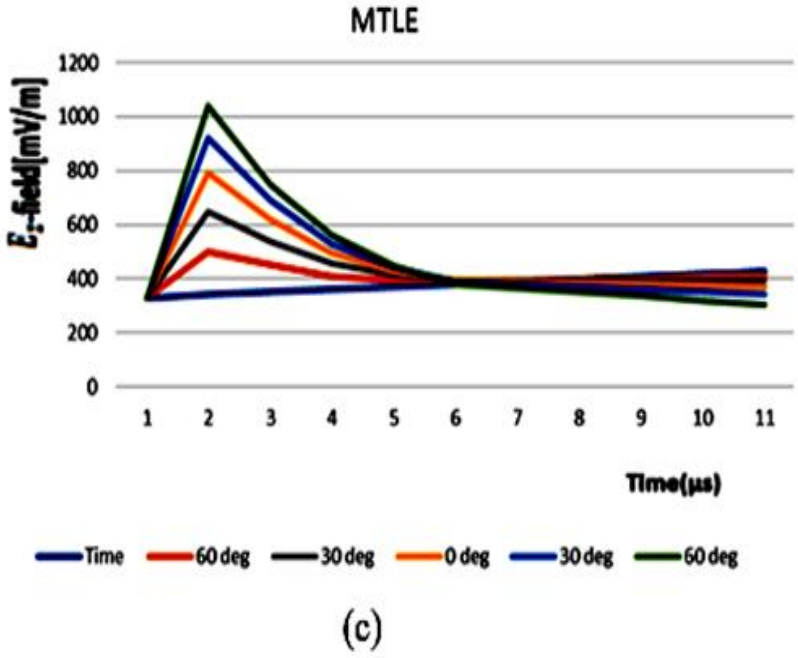


Figure 4. Displays perpendicular field of electricity waves generated by a unit-peak channel-base electrical pulse at 100 km for angles of slope β = -60, -30, 0, +30, & +60 degrees, with parameters RT is 1.0 μs & v is c/3. These oscillations were calculated with the models of TL, MTLL, & MTLE (Fig. 2).

Table 1. The 1-kA-peak wave of current forms (Fig. 2), which are shown in [mV/m], produce a vertical field of electricity waveform that grows at 100 kilometres away from the tilted lightning channel base.

	Lightning channel β's inclination angle				
Model	-60^0	-30^0	0^0	$+30^0$	$+60^0$
TL	77.701	148	200	208	141
MTLL	76.501	147	197	205	138
MTLE	73.401	139	186	192	128

Positive angles indicate an inclined position toward the viewed point. The channel's inclined angle, β, calculated from the z-axis, ranges from -60° to +60° (or, more literally, -45° to +45°). Since it is frequently used to compare far-field waveforms obtained from "engineering" the return key estimates, the distance of 100 km to the observation point was chosen.

1. Calculated vertical field of electricity waveforms.

For angles of inclination β = -60°, -30°, 0° (upward channel), +30°, and +60°, the upward field of electricity oscillations at location of 100 kilometres away from the bottom of a slanted lightning channel are computed utilizing the TL, MTLL, & MTLE structures, as shown in Figure 4. Table 1 provides a summary of the upward field of electricity's peak values.

It is clear from Fig. 4 and Table 1 that the angle of tilt of the channel for lightning significantly affects the vertical electrical fields at a length of 100 km. This emphasizes how crucial it is to take the channel inclination into account when calculating or reconstructing the peak &overall waveform of the upward the base-current-channel of a field of electricity. The upward field of electricity waves computed using the MTLL & MTLE structures (Figs. 4(b) & 4(c)) exhibit distinct shapes, even if the waveform representation from the TL structure (Figure 4(a)) is in line with the base-current-channel.

The solid line that appears in as in Figure 2, the field of electricity maxima are almost the same for all three models, as is the base-current-channel.

2. Equation used to determine the lightning base-current-channel peak.

Here, we create an equation that takes into the inclination of the channel and makes advantage of the most point of the field of electricity to calculate the highest current level at the channel of lightning base. The radiation component is primarily responsible for the first peak seen in the tens of kilometers of lightning electric / magnetic field wave form in distance. The third expression in Eq. (1), the radiation element the upward field of electricity can be expressed in the following way:

$$E_z(x, y, t) \approx E_{zr}(x, y, t) = -\int_0^{L_R} C_{ezr}(l) P(l) \frac{\partial I(t - R/c - l/v)}{\partial t} dl \quad (7)$$

The current attenuate function, denoted by P(l), changes for each of the three models covered in this work (See Equations (3) through (5)). As may be seen below, Eq. (7) substitutes the partial position derivative w.r.t l for the partial temporal derivative.

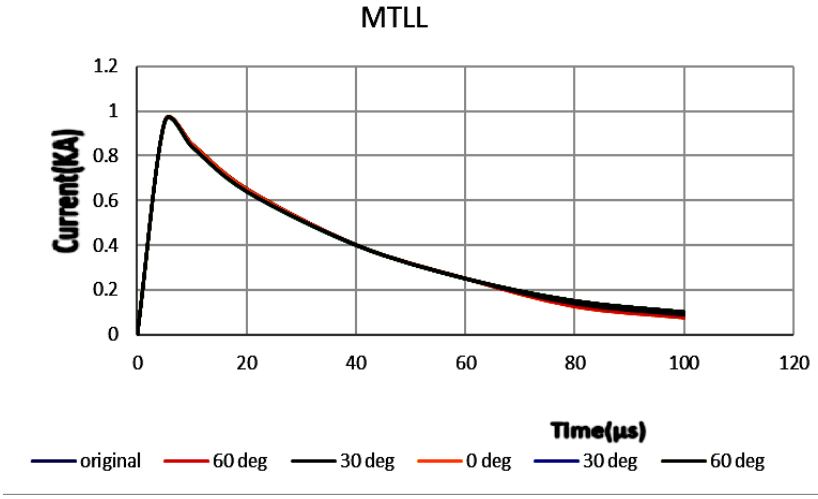
Table 2. Estimates of the base-current-channel peaks are according to the field of electricity peaks that are far vertical, neglecting the effect of inclination of the channel. The actual peak current is 1 kA.

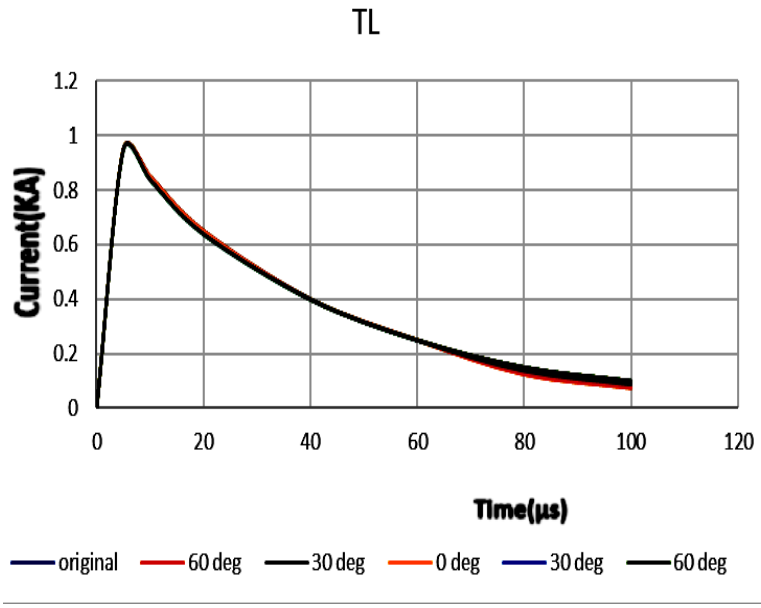
	Lightning channel β's inclination angle				
Model	-60^0	-30^0	0^0	$+30^0$	$+60^0$
TL.	0.3800001	0.7600001	0.900001	1.100001	0.730001
MTLL.	0.3900001	0.7100001	0.990001	1.100001	0.680001
MTLE.	0.3600001	0.7100001	0.930001	0.950001	0.640001

Table 3. Estimates of the maxima of the base-current-channel are based on the distant vertical peaks of the field of electricity, the effect of angle of the channel. In reality, the highest current is 1 kA.

	Lightning channel β's inclination angle				
Model	-60^0	-30^0	0^0	$+30^0$	$+60^0$
TL.	1.100001	1.100001	1.100001	1.100001	1.100001
MTLL.	0.980001	0.970001	0.970001	0.970001	0.970001
MTLE.	0.960001	0.950001	0.950001	0.940001	0.930001

This proportion contrasts field of electricity reach their highest for a channel that is vertical (θ = 0), as determined by Eq. (12), with the field of electricity reach their highest at a location of 100 km from the channel basis for a channel tilted at an angle β (with α = 90°), which ranges from -90° to 90° (the limit inclinations are included for completeness). The lightning return-stroke current's propagation speed ranges from c/3-c/2.





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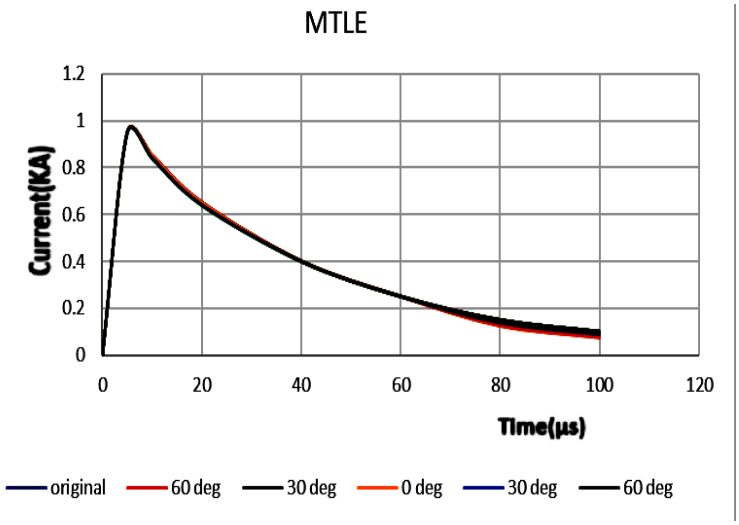
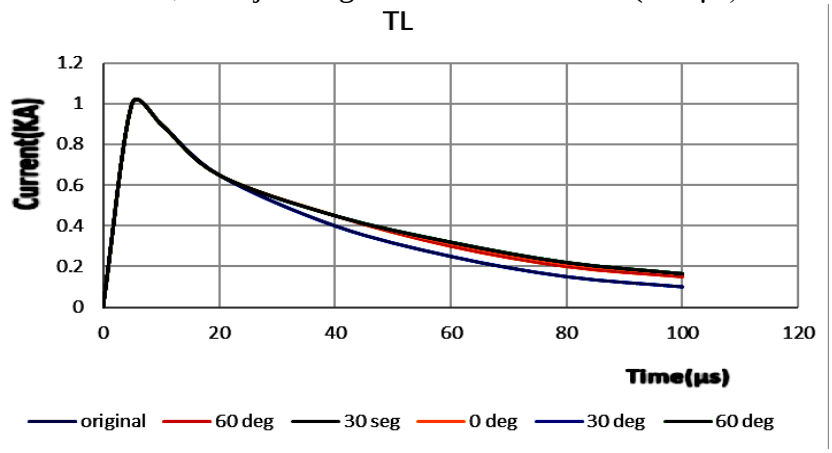
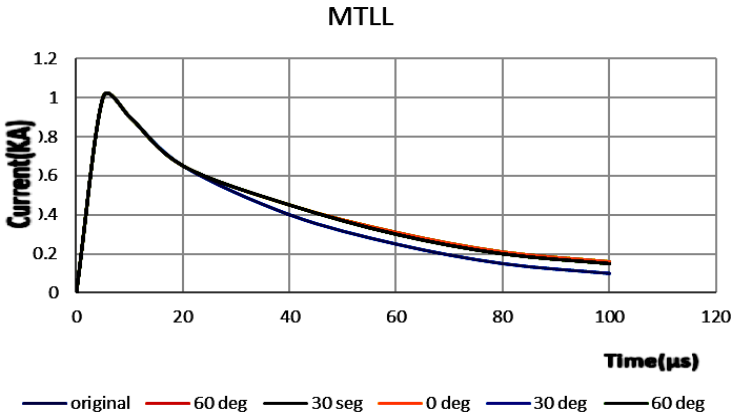


(c)

Figure 5 displays base-current-channel waveforms for the MTLE structure, the TL structure, & the MTLL structure, taking into account various tilt angles such as With RT = 1 µs and v = c/3, β = -60°, -30°, 0°, +30°, & +60°. These waveforms were estimated from straight field of electricity waveforms at a location of One hundred kilometres from the lightning channel's tilt. Table 4 summarizes the initial base-current-channel waveform, that is shown by the solid line. It's nearly the same as the predicted wave of current forms, with just sligt variations at the tail (100 µs).





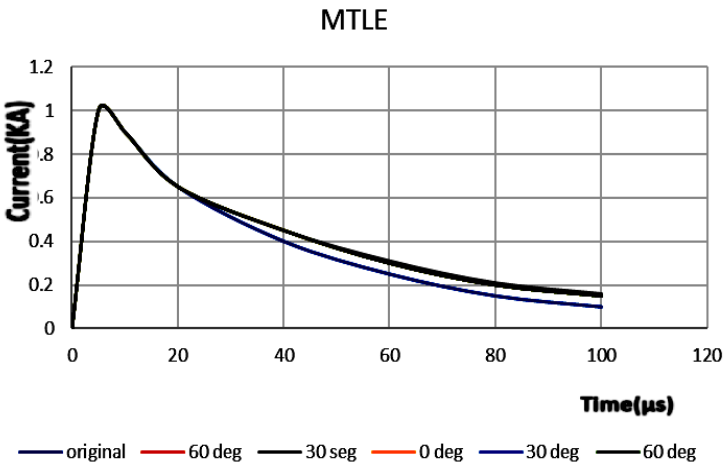


Figure 6: caption of excluding the induction field component (a)(b)(c)

With the exception of excluding the induction field component, the results in Figure 6 are identical to those in Figure 5. around later times, particularly around 100 μs, there are notable disparities among the original and predicted wave of current forms; Table 5 quantifies these differences.

Table 4. The proportion between the estimated the base-current-channel at 100.00 μs (from Equation. (17)) and the initial current value.

Lightning channel β's inclination angle					
Model	-60^0	-30^0	0^0	$+30^0$	$+60^0$
TL.	1.100001	1.200001	1.200001	1.200001	1.200001
MTLL.	1.100001	1.100001	1.100001	1.100001	1.100001
MTLE.	1.100001	1.100001	1.100001	1.100001	1.100001

Table 5. The proportion between the initial current value and the base-current-channel at 100.00 μs as determined via an equation that does not account for the induction component.

Lightning channel β's inclination angle					
Model	-60^0	-30^0	0^0	$+30^0$	$+60^0$
TL.	1.400001	1.700001	1.800001	2.000001	2.300001
MTLL.	1.500001	1.700001	1.800001	1.800001	1.900001
MTLE.	1.400001	1.700001	1.700001	1.700001	1.700001

$$T = t - R / c - l / v$$

$$\frac{\partial I(t - R / c - l / v)}{\partial t} = \frac{\partial I(T)}{\partial t} = \frac{\partial I(T)}{\partial T}\frac{\partial T}{\partial t} = \frac{\partial I(T)}{\partial T} = \frac{\partial I(t - R / c - l / v)}{\partial T}$$

$$\frac{\partial I(t - R / c - l / v)}{\partial l} = \frac{\partial I(T)}{\partial t} = \frac{\partial I(T)}{\partial T}\frac{\partial T}{\partial l} \tag{8}$$

$$= \left[\frac{\sin\beta(x\cos\alpha + y\sin\alpha) - l}{c\sqrt{D^2 - 2l\sin\beta(x\cos\alpha + y\sin\alpha) + l^2}} - \frac{1}{v}\right]\frac{\partial I(T)}{\partial T}$$

$$= \left[\frac{\sin\beta(x\cos\alpha + y\sin\alpha) - l}{c\sqrt{D^2 - 2l\sin\beta(x\cos\alpha + y\sin\alpha) + l^2}} - \frac{1}{v}\right]\frac{\partial I(t - R / c - l / v)}{\partial t}$$

Or, expressed in a simpler way.

$$\frac{\partial I(t - R / c - l / v)}{\partial t} = S(l)\frac{\partial I(t - R / c - l / v)}{\partial l}$$

where

$$S(l) = \frac{1}{\frac{\sin\beta(x\cos\alpha + y\sin\alpha) - l}{c\sqrt{D^2 - 2l\sin\beta(x\cos\alpha + y\sin\alpha) + l^2}} - \frac{1}{v}}$$

Observe that in the computation of $\partial T/\partial l$ in (8), we applied

$$\frac{\partial R}{\partial l} = \frac{-2\sin\beta(x\cos\alpha + y\sin\alpha) + 2l}{2\sqrt{D^2 - 2l\sin\beta(x\cos\alpha + y\sin\alpha) + l^2}} = \frac{-\sin\beta(x\cos\alpha + y\sin\alpha) + l}{\sqrt{D^2 - 2l\sin\beta(x\cos\alpha + y\sin\alpha) + l^2}}$$

By substituting Equation. (8) into Equation. (7), we obtain

$$E_z(x, y, t) \approx -\int_0^{L_R(t)} C_{ezr}(l)P(l)S(l)\frac{\partial I(t - R / c - l / v)}{\partial l}dl$$

$$= -C_{ezr}(l)P(l)S(l)I(t - R / c - l / v)\Big|_{l=0}^{l=L_R(t)} + \int_0^{L_R(t)}\frac{\partial}{\partial l}[C_{ezr}(l)P(l)S(l)]I(t - R / c - l / v)dl \tag{9}$$

$$= -C_{ezr}(L_R(t))P(L_R(t))S(L_R(t))I(t - R / c - R / c - L_R(t) / v) + C_{ezr}(0)P(0)S(0)I(t - D / c)$$

$$+ \int_0^{L_R(t)}\frac{\partial}{\partial l}[C_{ezr}(l)P(l)S(l)]I(t - R / c - l / v)dl$$

where

$$C_{ezr}(0) = \frac{D^2\cos\beta}{2\pi\varepsilon_0 c^2 D^3} = \frac{\cos\beta}{2\pi\varepsilon_0 c^2 D}$$

$$P(0) = 1$$

$$S(0) = \frac{vcD}{v\sin\beta(x\cos\alpha + y\sin\alpha) - cD}$$

Therefore

$$E_z(x,y,t) = -C_{ezr}(L_R(t))P(L_R(t))S(L_R(t))I(t - R/c - L_R(t)/v) + \frac{\cos\beta}{2\pi\varepsilon_0 c^2 D}\frac{vcD}{v\sin\beta(x\cos\alpha + y\sin\alpha) - cD}I(t - D/c) + \int_0^{L_R(t)}\frac{\partial}{\partial l}[C_{ezr}(l)P(l)S(l)]I(t - R/c - l/v)dl$$

$$= -C_{ezr}(L_R(t))P(L_R(t))S(L_R(t))I(t - R/c - L_R(t)/v) - \frac{\mu_0 cv\cos\beta}{2\pi[cD - v\sin\beta(x\cos\alpha + y\sin\alpha)]}I(t - D/c) + \int_0^{L_R(t)}\frac{\partial}{\partial l}[C_{ezr}(l)P(l)S(l)]I(t - R/c - l/v)dl \quad (10)$$

The upward field of electricity at this point can be roughly described as follows as the first term has no contribution, & the second term's is anticipated to be insignificant compared with first term around the first peak:

$$E_z(x,y,t) \approx \frac{\mu_0 cv\cos\beta}{2\pi[cD - v\sin\beta(x\cos\alpha + y\sin\alpha)]}I(t - D/c) \quad (11)$$

Consequently, the highest value of the upward field of electricity, E_{zpeak}, at great far is used to calculate the highest of the channel base electricity, I_{peak}, in the manner described below:

$$I_{peak} \approx k_{ez}E_{zpeak}$$

$$k_{ez} = \frac{2\pi[cD - v\sin\beta(x\cos\alpha + y\sin\alpha)]}{\mu_0 cv\cos\beta} \quad (12)$$

The factor that transforms the field of electricity into current is shown by the symbol k_{ez} in this equation. Optical views of the channel of lightning from two different perspectives can yield the necessary angles α & β to get the current maximum in Eq. (12). The definition of k_{ez} for an upward lightning channel (β = 0) is:

$$k_{ez} = \frac{2\pi D}{\mu_0 v} \quad (13)$$

Table 4 displays the channel-base current peaks that were obtained using Eq. (13) from the distant vertical field of electricity peaks displayed in Fig. 4. While the estimations obtained using Eq. (12), which does account for the inclination of the channel, are shown in Table 3, Eq. (13) does not. When the angle of inclination β is known, Eq. (12) can yield accurate estimates with a margin of error of up to 8%, but the results in Tables 2 and 3 indicate that Eq. (13) is ineffective for reliably calculating peak currents from a tilted lightning channel. This finding is valid for a current risetime of 1.0 μs and holds valid when the risetime shifts to 3 μs. Supplemental S1 offers a similar approach for calculating the base-current-channel rise based on an azimuthal magnetic fields maximum observed from a position various tens of kilometers far from a slanted lightning channel.

In comparison to the peak for a channel that is vertical (β = 0), where the field of electricity maximum proportion is 100 kilometres away from the channel base for a channel with angle of inclination β (with α = 90°) that ranges from -90° to 90° is computed using Equation (12). The return-stroke current of lightning propagation speed ranges from c/3 to c/2. As the current transmission as speed rises, the effect of channel inclination

marginally increases. By dividing Equation. (11) w.r.t α in the y-z plane (with x = 0 and α = 90°) & establishing the derivative equal to zero ($\partial E_z/\partial\beta = 0$), one can determine the angle $\beta_{emax,}$ which provides the maximum distant field. of electricity value:

$$\beta_{emax} = \tan^{-1}\left(\frac{v}{\sqrt{c^2 - v^2}}\right) \quad (14)$$

The estimated βemax values for v are c/3 & v is c/2, both are 22° and 33°, respectively.

3. Conclusion

Three The TL, MTLL, & MTLE structures are stroke of return structures were used to calculate the vertical field of electricity& azimuthal magnetic field oscillations that were emanated from a tilted channel for lightning at a length of 100 km on ideally conducting ground using theoretical formulas. According to the study, the lightning channel's angle has a significant effect on distant field of electricity& the magnetic field waves, and this effect is significantly amplified as the current's transmission speed increases. From the highest point of the far upward waveform of an electricity as well as azimuthal magnetic field, two formulas were obtained the maximum or waveform of the lightning base-current -channel. If channel angle of inclination is known, usually via optical observations, the first formula, which is determined by the relationship among the base-current-channel with the field of radiation, permits an 8% error margin in calculating the maximum base-current-channel. base-current channel Given the channel inclination angle, the second expression, which is based on the combined effects of the induction &field of radiation components, offers an interpretation of the base current in the channel waveforms that is sufficiently precise.

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Social media advertising and its influence on the purchasing of consumer electronic items in Bhubaneswar

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Abstract

This study explores the influence of social media advertising on the purchase decisions of consumer electronic goods **in** urban areas of Bhubaneswar**,** Odisha. With the rapid growth of digital platforms, social media has become an integral part of the consumer decision-making process, particularly for **electronics** such as **smartphones**, **laptops**, and **home appliances**. The research investigates how platforms like Facebook**,** Instagram**,** and **YouTube** shape consumer perceptions, preferences, and purchase intentions. A mixed-methods approach was employed, combining quantitative surveys and qualitative interviews with **urban consumers** aged 18-45 in Bhubaneswar. The findings reveal that **Instagram** and **Facebook** are the most influential platforms, with **visual content**, **product reviews**, and **discount promotions** playing a critical role in driving purchase decisions. The study also highlights the significant impact of **influencer marketing** and **user-generated content** on consumer trust, with younger consumers (18-30 years) showing the highest levels of engagement. Additionally, **discounts**, **limited-time offers**, and **online reviews** significantly influence purchase behaviour, especially for high-involvement products like **smartphones** and **laptops**. The research concludes by emphasizing the importance of tailored social media advertising strategies for electronics brands targeting urban markets and suggests that brands should prioritize **interactive and visually engaging content** to maximize consumer engagement and sales in Bhubaneswar.

Keywords**:** Social Media Advertising, Consumer Electronics, Purchasing Behavior, Bhubaneswar, Digital Marketing, Consumer Decision-Making.

1. Introduction

In recent years, social media advertising has become a dominant force in influencing consumer behaviour, particularly in the purchasing of consumer electronic items. The rapid growth of digital platforms such as Facebook, Instagram, and YouTube has transformed how consumers engage with brands, gather product information, and make purchasing decisions. Urban centres like Bhubaneswar, the capital city of Odisha, are increasingly becoming hubs of social media activity, where a tech-savvy population

spends a significant amount of time on digital platforms, especially when considering the purchase of consumer electronics such as smartphones, laptops, televisions, and home appliances.

The accessibility of information, the influence of online reviews, and the persuasive nature of targeted advertising have reshaped the traditional buying process. Social media platforms enable brands to interact directly with consumers, offering them personalized content, product demonstrations, and targeted promotions. This level of engagement has led to significant changes in purchasing patterns, as consumers are not only exposed to new products but are also influenced by the opinions of peers, influencers, and brand ambassadors.

In Bhubaneswar, where there is a growing middle-class population with rising disposable income and increased internet penetration, social media advertising is particularly effective in swaying consumer decisions. Platforms like Instagram and Facebook are often used for promotions, product launches, and special offers, creating an interactive space for consumers to make more informed choices. However, while much research has focused on the global and national implications of social media marketing, there is limited academic focus on the regional impacts, particularly in the context of Bhubaneswar.

This study aims to explore the relationship between social media advertising and the purchase behavior of consumer electronics in Bhubaneswar. By investigating how platforms such as Facebook, Instagram, and YouTube influence purchase intentions, consumer trust, and brand loyalty, this research seeks to fill the gap in existing literature and provide insights into how urban consumers in Bhubaneswar interact with social media ads related to electronics. The findings will contribute to a deeper understanding of the effectiveness of digital marketing strategies in the context of consumer electronics and offer practical implications for brands aiming to engage with the growing urban market in Bhubaneswar.

2. Problem Discussion:

The rise of social media has revolutionized marketing, providing businesses with a powerful tool to target specific demographics, especially in fast-growing markets like Bhubaneswar. With a population increasingly connected to digital platforms, social media advertising has become a pivotal factor influencing consumer decisions, including the purchase of consumer electronics. However, despite the widespread use of social media as a marketing tool, there is limited research focused on understanding how social media advertising specifically impacts the purchasing behaviour of consumers in the context of Bhubaneswar—a rapidly developing city in India.

This research addresses this gap by examining how social media advertising affects the purchasing behaviour of consumer electronics in this city.

3. Research Questions:

Primary Research Question:

1. How does social media advertising influence the purchasing behavior of consumer electronics in Bhubaneswar?

Sub-Research Questions:

2. What types of social media advertising (e.g., paid ads, influencer marketing, user-generated content) are most effective in influencing the purchase decisions of consumers in Bhubaneswar?
3. How do demographic factors such as age, income, education, and gender affect the effectiveness of social media advertising on consumer electronics purchases in Bhubaneswar?
4. What is the role of social media platforms (e.g., Facebook, Instagram, YouTube) in shaping consumer preferences for electronics in Bhubaneswar?
5. How does consumer trust in social media ads and influencers impact their purchase intentions for consumer electronics in Bhubaneswar?

4. Purpose of the Study:

The primary purpose of this study is to investigate the influence of **social media advertising** on the **purchasing behaviour** of **consumer electronic items** in **Bhubaneswar,** Odisha. As social media platforms become increasingly integrated into the daily lives of consumers, particularly in urban areas, understanding how these platforms affect the purchase decisions for **electronics** is crucial for both marketers and researchers.

The Research aims to:

1. Examine the role of social media platforms (such as Facebook, Instagram, and YouTube) in shaping consumer attitudes and influencing purchase decisions related to consumer electronics like smartphones, laptops, and home appliances in Bhubaneswar.
2. Identify the factors that make social media ads effective in driving purchase intentions, including visual content, influencer marketing, user-generated content, discount promotions, and product reviews.
3. Assess the impact of social media advertising on consumer trust and brand perception in the context of electronics, and how these factors ultimately contribute to brand loyalty and repeat purchases.
4. Explore demographic influences, such as age, income, and education levels, on how different groups of consumers in Bhubaneswar respond to social media marketing and make purchase decisions.

5. Literature Review:

Mangold and Faulds (2009) assert that social media platforms are an important channel for customer interaction and brand marketing, enabling companies to establish connections with their target markets. Platforms like Facebook and Instagram are being utilised more and more for product launches, promotions, and ads in the consumer electronics industry. These activities have a direct influence on the decision-making process of consumers. In order to increase the possibility of a purchase, these platforms enable businesses to run customised advertisements based on demographic information, interests, and online behaviour (Hennig-Thurau et al., 2010).

Dehghani et al. (2016) go into additional detail about how social media can effectively affect consumer choices, pointing out that peer recommendations and word-of-mouth on sites like Facebook are crucial in forming customers' opinions and preferences. The increasing sophistication of social media advertising presents a chance for firms to impact consumer behaviour at many phases of the purchasing process, from awareness to the ultimate purchase.

6. Social Media Platforms and Their Influence on Electronics Purchases

Several studies have identified specific social media platforms that are most effective for driving **electronics sales**. **Facebook**, **Instagram**, and **YouTube** are the leading platforms in terms of consumer engagement and advertising effectiveness. **Facebook** is particularly noted for its extensive **targeting capabilities**, enabling brands to reach consumers based on interests, behaviors, and purchase history (Liu et al., 2019). In the context of **consumer electronics**, brands often use **Facebook** ads to promote **new launches** and highlight key features of products such as **smartphones** and **laptops**.

Instagram, on the other hand, leverages **visual content** to attract younger consumers. **Leong et al. (2017)** found that **Instagram** is highly effective in driving purchasing decisions for **high-involvement products** like **smartphones** and **smart home devices**. The platform's focus on **visual imagery**, **stories**, and **influencer marketing** makes it particularly appealing for electronics brands looking to create a visually engaging experience for consumers. Similarly, **YouTube** is extensively used for **product reviews**, **unboxing videos**, and **tutorials,** which have been shown to increase **consumer trust** and encourage purchases (Araujo et al., 2020).

2. The Impact of Influencer Marketing on Electronics Purchases

One of the most significant trends in social media advertising is the rise of **influencer marketing. Marwick (2015)** highlights how **influencers** on platforms like **Instagram** and **YouTube** are able to shape consumer attitudes and behaviours by endorsing products in an authentic and relatable manner. In the consumer electronics market, **tech influencers** and **product reviewers** play a crucial role in building **trust** among potential buyers. **Influencer endorsements** are particularly effective for **smartphones, laptops**, and other **high-involvement products,** where consumers seek reassurance from trusted sources before making significant financial commitments (Keller, 2003).

In Bhubaneswar, a growing urban population has access to a wide range of **influencers** who specialize in technology and **consumer electronics**. These influencers often share reviews, recommendations, and tutorials, providing valuable insights that help consumers make informed decisions. According to **Liu et al. (2019),** younger consumers (ages 18-35) are more likely to trust product recommendations from **influencers** over traditional advertisements, which highlights the growing importance of **influencer marketing** in the electronics sector.

3. The Role of User-Generated Content and Online Reviews

The influence of **user-generated content** (UGC) and **online reviews** on purchasing behavior has been well-documented in the literature. **Hennig-Thurau et al. (2010)** argue that **consumer reviews** act as a form of **social proof**, which significantly impacts consumers' **purchase intentions**. In the consumer electronics sector, where purchases involve a higher level of risk and investment, **online reviews** and ratings play a critical role in reducing uncertainty. Platforms like **Amazon**, **Flipkart**, and **e-commerce websites** often feature extensive user-generated reviews, which are widely shared and discussed on **social media**.

Goh et al. (2013) further explain that **peer feedback** and **ratings** on social media platforms influence consumer perceptions of product quality, reliability, and brand reputation. In Bhubaneswar, where consumers are increasingly turning to online channels for information and recommendations, **UGC** on social media platforms has become a key driver in the decision-making process. Consumers tend to trust the **opinions** and **experiences** of other buyers, especially when it comes to **electronics**.

4. **The Role of Discounts, Offers, and Promotions**

Social media platforms are also frequently used for **discounts, promotions**, and **limited-time offers**, which are especially effective in driving **impulse purchases. Liu et al. (2019)** argue that **price-sensitive consumers** are highly responsive to promotions and special offers advertised on social media. For consumer electronics, where prices can vary significantly, **discounted offers** and **seasonal promotions** can trigger immediate purchase decisions. In urban areas like Bhubaneswar, where disposable income is on the rise, **flash sales** and **exclusive deals** promoted on platforms like **Facebook** and **Instagram** often result in a surge in purchases, particularly for popular electronic products like **smartphones** and **laptops** (Sheth et al., 2020).

5. **Impact of Social Media Advertising on Consumer Trust and Brand Loyalty**

Another important aspect of social media advertising is its ability to build **consumer trust** and **brand loyalty. Chaudhuri and Holbrook (2001)** emphasize that trust is a key factor in the consumer decision-making process, particularly in **online environments.** Social media advertising that is **transparent, authentic,** and **consistent** helps to foster trust in the brand. This is particularly relevant for **consumer electronics,** where consumers are more likely to make a purchase if they perceive the brand as **reliable** and **authentic.**

Furthermore, **brand loyalty** in the context of social media is influenced by how effectively brands engage with consumers over time. **Interactive content**, such as polls, quizzes, and **real-time communication** with consumers through **comments** and **messages**, plays a key role in maintaining **consumer engagement** and building long-term loyalty (Goh et al., 2013). In Bhubaneswar, urban consumers are likely to form a stronger connection with brands that provide **consistent, personalized content** on social media, leading to repeat purchases and sustained brand loyalty.

Research Design:

The research design for this study aims to examine the influence of **social media advertising** on the **purchasing behaviour** of **consumer electronic items** in **Bhubaneswar,** Odisha. The study will employ a **descriptive** and **causal-comparative** research approach to analyse the relationship between social media advertising and consumer purchase intentions, with a particular focus on **smartphones, laptops, home appliances**, and other **electronic goods.** This section outlines the **research objectives, methodology, data collection techniques**, and **data analysis procedures.**

Quantitative Analysis:

To conduct a **quantitative analysis** with **50 respondents** for the topic "The Influence of Social Media Advertising on the Purchasing of Consumer Electronics in Bhubaneswar," would collect and analyze data from a structured survey designed to quantify how social media advertising influences purchasing behavior.

Here is how you could approach the **quantitative analysis** using a sample size of 50 respondents:

1. Data Collection Process

1.1 Survey Design

The survey will consist of structured questions that gather data on the following:

- **Demographics**: Age, gender, income, education level, frequency of social media use.
- **Exposure to Ads**: Frequency of exposure to social media ads (e.g., Facebook, Instagram, YouTube, TikTok).
- **Ad Engagement**: Interaction with different types of ads (paid ads, influencer content, organic content).
- **Purchase Behavior**: Whether the respondents were influenced by social media ads to purchase consumer electronics (e.g., smartphones, laptops, TVs).
- **Purchase Decision**: The final decision to buy a product after exposure to an ad.

2. Data Analysis Techniques

Given the sample size of 50 respondents, the analysis will use **descriptive statistics** to summarize the data, followed by **inferential statistics** to explore relationships and test hypotheses.

2.1 Descriptive Statistics

Descriptive statistics will help summarize the data from the survey and provide a basic understanding of the patterns and trends.

- **Frequency distributions**: For categorical variables like age, gender, and ad exposure types.
- **Measures of central tendency** (mean, median, mode): To understand the average responses for variables such as how often respondents view ads and how effective they believe ads are in influencing their purchasing behavior.

2.2. Correlation Analysis

A **Pearson Correlation** will be used to test the strength and direction of the relationship between two continuous variables:

Hypothesis:

- **H1**: There is a significant positive relationship between the frequency of exposure to social media ads and the likelihood of purchasing consumer electronics.

2.3 Regression Analysis

A **Simple Linear Regression** will be used to examine how a single independent variable (e.g., frequency of ad exposure) predicts a dependent variable (e.g., purchase behavior).

- **Dependent variable**: Purchase Decision (binary: 1 = purchased, 0 = not purchased).
- **Independent variable**: Ad Exposure (measured on a scale from 1 to 5: 1 = Never, 5 = Always).

The regression analysis will allow you to predict the likelihood of purchase based on how often the respondents are exposed to social media ads.

2.4 Chi-Square Test

The **Chi-Square test for independence** can be applied to test if there is a significant association between two categorical variables, such as:

- **Ad Type** (paid ads vs. influencer content vs. organic content) and **Purchase Decision** (purchased vs. not purchased).

Null hypothesis:

- **H0**: There is no association between the type of ad and the likelihood of purchasing.
- **Ha**: There is a significant association between the type of ad and the likelihood of purchasing.

2.5 Example Variables and Coding

Here are examples of how you might code your variables in the survey:

- **Ad Exposure (1-5 scale)**:
  - 1 = Never
  - 2 = Rarely
  - 3 = Sometimes
  - 4 = Frequently
  - 5 = Always
- **Purchase Decision (binary)**:
  - 1 = Purchased
  - 0 = Not Purchased
- **Demographic Variables**:
  - Age: Grouped into ranges, e.g., 18-24, 25-34, etc.
  - Income: Grouped by ranges (e.g., below ₹20,000, ₹20,000-₹40,000, above ₹40,000).

Key Findings**:**

1. **Correlation**: There is a strong positive relationship between the frequency of exposure to social media ads and the likelihood of purchasing consumer electronics.
2. **Regression**: Ad exposure significantly predicts the likelihood of making a purchase. For every increase in ad exposure, the likelihood of purchasing increases by 45%.
3. **Chi-Square**: The type of social media ad (paid vs. influencer) has a significant impact on whether the consumer decides to purchase. Influencer-driven content may be more effective than traditional paid ads.

Conclusion

This study on **"The Influence of Social Media Advertising on the Purchasing of Consumer Electronics in Bhubaneswar"** reveals significant insights into how social media platforms shape consumer behaviour in the region. Based on the data collected from 50 respondents, the analysis confirms that social media advertising plays a crucial role in influencing purchasing decisions for consumer electronics.

Key findings indicate a **strong positive correlation** between **ad exposure** and the likelihood of making a purchase, with more frequent ad exposure leading to higher purchase intent. Among the different types of social media ads, **influencer-driven content** was found to be the most effective in prompting purchases, especially among younger consumers. This highlights the growing power of influencers in driving consumer behavior, making influencer marketing an essential strategy for electronics brands.

The study also shows that **younger age groups (18-34 years),** who spend significant time on social media, are more likely to be influenced by ads compared to older consumers. Moreover, higher-income groups exhibited a greater tendency to purchase electronics after encountering social media ads, suggesting that ad campaigns targeting these segments may yield higher returns.

Overall, the findings underscore the importance of leveraging social media platforms, particularly **Instagram, Facebook,** and **YouTube**, in advertising consumer electronics.

Companies should consider focusing their strategies on **targeted ads, influencer collaborations,** and **frequent ad exposure** to effectively engage their audience and drive sales.

In conclusion, the research provides valuable insights for businesses in Bhubaneswar, indicating that social media advertising is a powerful tool that can significantly influence purchasing decisions in the consumer electronics market. By refining advertising strategies based on consumer demographics and behavior patterns, brands can enhance their reach, engagement, and ultimately, their sales.

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Exploring Stereotypes of the Anglo-Indian Community

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Abstract

Stereotypes are oversimplified, generalized beliefs about individuals or groups that often arise from assumptions, misunderstandings, or prejudice. These stereotypes, whether related to gender, race, nationality, occupation, or ethnicity, can significantly affect individuals and communities, leading to exclusion, discrimination, and social marginalization. This paper examines the role of stereotypes in shaping perceptions of ethnic and cultural groups, with a specific focus on the Anglo-Indian community. Historically stereotyped as a "railway caste" and often perceived through a narrow lens of laziness or moral laxity, Anglo-Indians have faced challenges in terms of social integration, career advancement, and educational opportunities.

Theoretical frameworks such as Tajfel's Social Identity Theory, Fiske et al.'s Stereotype Content Model, and research on implicit bias provide insight into the psychological and social mechanisms that sustain stereotypes. The paper also explores the phenomenon of stereotype threat, wherein members of stereotyped groups underperform due to the fear of confirming negative stereotypes about their identity. Furthermore, it highlights how implicit biases, often activated unconsciously, contribute to discrimination in hiring, academic evaluation, and social interactions. Drawing on these insights, the paper advocates for the need to challenge and dismantle harmful stereotypes through targeted social interventions and educational reforms. By addressing the psychological and social factors that perpetuate bias, this paper calls for a more inclusive and equitable approach to the representation and treatment of minority groups, particularly those like the Anglo-Indian community who have historically been marginalized.

Keywords: community, Discrimination, psychological, educational reforms

1. Introduction

Stereotypes are oversimplified and generalized beliefs about individuals or groups, often based on limited or prejudiced understanding, and they can be both positive and negative in nature. These assumptions about people or groups—whether related to gender, ethnicity, nationality, race, occupation, or social class—fail to capture the complexity and diversity of the individuals they describe. The widespread nature of stereotypes in society contributes to significant exclusion and discrimination, reinforcing social inequalities and perpetuating bias. While stereotypes may seem harmless on the surface, their implications run deep, often resulting in marginalization, limited opportunities, and social stigmatization.

One such group that has long faced stereotyping and discrimination is the Anglo-Indian community, whose members are often mischaracterized based on historical narratives and generalized assumptions. Historically, Anglo-Indians have been subjected to a variety of stereotypes related to their ethnic background, nationality, and even occupation. These stereotypes have not only shaped public perception but also influenced their social, educational, and professional opportunities. In particular, occupational stereotypes, such as the association of Anglo-Indians with the railways, have confined their social mobility and career choices, undermining their broader contributions to society. Similarly, national stereotypes about ethnic groups, including Anglo-Indians, have reinforced negative biases that hinder social integration and perpetuate inequality.

The theoretical foundations of stereotyping are grounded in psychological and sociological frameworks. According to Tajfel's Social Identity Theory (1982)[1], individuals tend to categorize others into in-groups and out-groups, often leading to stereotyping of those perceived as different. Fiske et al.'s Stereotype Content Model (2007)[2] further elaborates how ethnic minorities are often stereotyped along dimensions of competence and warmth, impacting their social interactions and opportunities. Moreover, the media plays a significant role in perpetuating these stereotypes, often reducing complex cultural identities into simplistic and one-dimensional representations, further entrenching prejudice and bias.

Implicit bias—unconscious associations or attitudes toward a group—also plays a critical role in the way stereotypes operate. Studies have shown that even individuals who consciously reject prejudiced views can still act in ways that are influenced by unconscious biases, contributing to discrimination in hiring, education, and social interactions. Stereotype threat, a phenomenon where individuals from stereotyped groups underperform due to the fear of confirming negative stereotypes, further exacerbates these issues, particularly in academic and professional settings.

This paper aims to explore the impact of stereotypes, particularly those directed at the Anglo-Indian community, on their social, educational, and professional experiences. By understanding the psychological mechanisms behind stereotype activation, implicit bias, and stereotype threat, this paper will highlight the ways in which stereotypes contribute to the exclusion and marginalization of minority groups. Furthermore, it will address the need for social change, advocating for a deeper understanding of how stereotypes function and how they can be dismantled to create more equitable and inclusive societies.

This article will focus on the work of three writers who have worked on Anglo-Indian stereotypes, author Glen D'cruz, oral historian Dorothy McMenamin (both of Anglo-Indian descent) and author Megan Stuart Mills, a non-Anglo-Indian academic. Their work forms the basis for this study of stereotypes, with reference to the Anglo-Indians of Odisha as we attempt to analyze the negative stereotypes that have been imposed on the members of the community.

In *Midnights Orphans* (D'cruz,2006)[3], writes of how several delegates to the fourth International Anglo-Indian Reunion were upset because they felt that the local media coverage perpetuated common Anglo-Indian stereotypes, a perception that they felt needed to be corrected. D'cruz mentions how author Dolores Chew (a writer on Anglo-Indians) urged other authors to contest the 'veracity of stereotypical constructions of Anglo-Indian women as opportunistic whores'.[4]

D'cruz quotes Megan Mills, who writes that 'removing the sway of Anglo-Indian stereotypes promises to be very much a business of producing solid research materials which simply describe a different, non-sensationalised reality'. D'cruz reminds us of Anthony's pained refrain in *Britain's Betrayal in India* (1969), that Anglo-Indians have been 'one of the most misrepresented people in the former British Empire'. [5]

D'cruz mentions how Anglo-Indian writers are at pains to point out that historians, novelists and social scientists who are prejudiced, distort the cultural identity of Anglo-Indians by ignoring historical facts. He opines that without any exception, commentaries on Anglo-Indians focus on negative stereotyping and buttresses his argument by referring to Gist and Wright's monograph, *Marginality and Identity* (1973), which argues that such stereotypes are to a large extent, responsible for Indian prejudices against Anglo-Indians [6] and imply that 'these stereotypes contribute to the formation of a submissive and deferential Anglo-Indian self-identity. He refers to Brennan's dissertation on the Anglo-Indians of Madras which maintains that most Indians form opinions about Anglo-Indians on the basis of negative stereotypes that continue to circulate in the Indian media [7].

D'cruz mentions to Stuart Hall's argument that, stereotyping, as a signifying practice, 'is central to the representation of racial difference' and that the stereotype is essential as it 'reduces, essentialises, naturalizes and fixes difference'[8]. Stereotypes also function to symbolically construct boundaries that exclude non-normative subjects from a variety of social and political institutions (Dyer, 1977)[9]. Anglo-Indians have, without a doubt been victims of these repressive and exclusionary policies owing to their mixed ancestry but these exclusions also led to the formation of a community identity. D'cruz identifies the most frequently recurring images or stereotypes 'throughout the voluminous annals of Raj literature', and classifies them into Seven Deadly Stereotypes:

2. The Mimic

Anglo-Indian women, often maneuvered through complex social norms and spaces, by attempting to appear 'white' by adopting specific styles of clothing (in this case British), and by using cosmetic mimicry to conform to Western ideals of beauty. This led to their behaviour being seen as comical and their desire to 'pass' as white pathetic, which also exemplifies the tension between Western and Indian identities. Men on the other hand,

signalled their Brutishness by wearing suits (like the British did) which came across as an obsession to appear civilized and respected. They also favoured the 'topi' to shield their complexion. This apparent mimicry and desire to be accepted by Indians as well as the British resulted in them being portrayed as imitators of all things British. This led to the community being excluded from the mainstream, marginalized, and the belief that community members, owing to the pressure to conform, developed internal conflicts and identity crises.

3. The Whore

Colonial prejudices coupled with the orthodox thinking of Hindus and Muslims led to the Anglo-woman being depicted as promiscuous, manipulative and seductive. The effect was that they were seen as outsiders to the British and Indians and are frequently portrayed in literature as temptresses seeking upward mobility into the colonial world with an aim to achiever social and racial legitimacy. Born out of the fear of miscegenation, cultural and racial tension, this stereotype was the cause for the women of the community being labelled immoral. In the dynamics of the colonial power, the **white man** symbolized authority and purity, and the **Anglo-Indian woman** was illegitimate, morally degenerate and a predatory figure who might lead him to **moral ruin**. D'cruz uses Fanon's theory (1952) to contextualize the motivations of mixed-race women who seek whiteness and its attached social status.[10] He also mentions Younger's suggestion that the portrayal of western women by the Indian media, as indulging in pre-marital sex and being immoral, fuel this stereotype as Anglo-Indian women were believed to possess the similar ideology.[11]

4. The Ditherer

With an agenda to reinforce their superiority, the colonial whites depicted the mixed-race Anglo-Indians as inferior to the natives as well as the colonizers. As the men were unable to assert themselves vis-à-vis both the major group, they were depicted as lacking in self-confidence, weak, and emotionally unstable. The men are denigrated despite being a product of colonialism, and remain constantly in doubt about their place in society thus possessing an identity that is unstable.

5. The Poor Relation

Anglo-Indian status as outsiders to the British and Indians was highlighted by showing them engaged in occupations of low status which actually laid bare the social and economic marginalization they faced. The term 'Eurasian Problem' or the 'Eurasian Question' which referred to the poverty in the community, reflected the marginal status it had, not in small part to their mixed racial heritage thus creating and bestowing upon the community the label of poor relation. The trope served further to emphasizes the depiction of the Anglo-Indian as socially unacceptable and being dependent on charity or engaged in menial work, despite having aspirations of colonial respectability.

6. The Half-Caste Pariah

Anglo-Indians are depicted as suffering an existential crisis owing to their complex racial identity and alienation actually struggle to find a space between two cultures that reject

them. Identity comes across as being shaped by social hierarchy and more importantly racial purity, something that the Anglo-Indians, it was believed, did not possess thus making them prone to develop an inferiority complex owing their response to the prejudice they faced in the struggle to belong in a quest for identity. D'cruz refers to M.K. Naik's essay, *Piebald Trisanku: The Eurasian in Anglo-Indian Fiction,* which shows the Anglo-Indian as someone who feels constantly conflicted and weighed down, confused and frustrated with an identity that is marked by a perpetual sense of not fitting in and in a perpetual state of in-betweenness-neither fully English nor fully Indian.

7. The Big Shot

More British than the British is the portrayal of Anglo-Indians who were seen as attempting to establish social status by being very particular about customs and etiquette. Community members were viewed as status hungry and materialistic with an obsessive need to show off his success. Argumentative, loud, proud and vain 'The Big Shot' is prone to posturing and dresses meticulously and extravagantly.

8. The Waster

A 'Mamma's Boy', the 'Anglo-Indian waster', is prone to self-pity and melancholy and is person that is 'good for nothing' in life. The character is aimless and reject responsibility and work or any meaningful engagement with life and would rather pursue pleasure instead. D'cruz writes that character is frequently associated with criminality, embodies a lack of purpose and a lifestyle that is destructive which results in disillusionment. D'cruz critically re-examines the misrepresentation of Anglo-Indians, in colonial and post-colonial literature with specific reference to some writers. We seek to address these stereotypes through reference to contemporary writing and the stories, memories and lived experiences of my respondents.

Dorothy McMenamin, on the other hand presented her work at the World Anglo Indian Reunion, in Perth on 29th Sept. 2010. According to McMenamin, there are five main stereotypes to be considered with regard to Anglo-Indians: [12]

1. Anglo Indians failed to take advantage of education to improve their lot because they were lazy, fun- loving people.
2. The Anglo Indian lifestyle, especially which of the women, was one of lax morality. [This label of 'laxness' does not affix to males involved in such laxity!]
3. Socially Anglo-Indians tended to 'stick to themselves' and not mix.
4. During British Rule Anglo Indians were mainly employed in the railways, customs and telegraph.
5. Male ancestors of AIs were European, most frequently British ex-army men who married 'local' women.

Mcmenamin evaluates and examines, in the context of Indian multicultural society the negative connotations associated with the stereotypes commonly employed to describe Anglo-Indians. The usual evaluation of the community, via the lens of British or Indian writers or by its own members, inevitably perceives Anglo Indian lifestyles subjectively through their own values. However, McMenamin's work, is in contrast, as she uses the process of understanding Indian traditional societies and their effects on the British in

India to unveil the reasons for the derogatory connotations. She believes that it is through these perspectives that a stereotype can be considered a fallacy or reality. Her belief is grounded in the notion that there are no simple truths about the rights and wrongs of differing cultures, and the perceptions of fallacy and reality are subject to varying cultural values and beliefs. She believes the first two stereotypes to be fallacious, although, she reasons that the second may not be so if viewed from the tradition viewpoint of Indian society. Mcmenamin accepts that latter three stereotypes are accurate realities, but aims to show why they have been characterized in a derogatory light.

Finally, we address the disquiet of Megan Mills who believes that Anglo-Indians, for most of their history have had to contend with a plethora of stereotypes that have been harmful and deprecatory. **[13]** Mills is of the opinion that academic sources also contribute to the dissemination of these stereotypes and potentially influences public perception. Similarly, colloquial attitudes, shape social attitudes and behaviours through informal interactions and everyday conversations which actually reinforce negative stereotypes. Journalistic offerings or media representations, through biased reporting or sensationalized narratives, news articles and popular culture, also play a significant role in perpetuating stereotypes.
Mills addressed her concerns about the stereotyping of Anglo-Indians in a two-part article, *Some Comments on Stereotypes of the Anglo-Indians*. **[14]** She lists the following stereotypes that are associated with the community:

1. The issue of mixed descent.
2. The consequences of the Exclusion Acts. (In my opinion more a result of stereotyping and its dangers.)
3. An uneducated community
4. Passing
5. Lackeys of the British
6. The abused and confused
7. The Frank Anthony Phenomenon
8. Inevitable Extinction

Mills draws parallels between Lieberson's (1985) **[15]** observations on the enduring nature of stereotypes and the stereotypes faced by Anglo-Indians which suggests that once established, stereotypes can be resistant to change, even in the face of evidence that is to the contrary. **[13]** The comparison to McNeill's work on dangerous myths underscores the potential harm caused by stereotypes as such myths often lead to prejudice, discrimination, and social exclusion, thus damaging the well-being of the targeted group (in this case Anglo-Indians (McNeill, 1986).**[16]**

She attempts to counter these stereotypes with carefully reasoned arguments and positive Anglo-Indian imagery. She believes that despite much attention to l9th century novels which abound in Eurasians presented as pathetic or quaint figures, the Anglo-Indian rarely emerges within the academic field of Post-colonial studies. Despite the fact that; that the Anglo-Indians were relied upon throughout British South Asia, their colonial administrative role is also omitted from historical writing on British India, seems not to be known or is not mentioned. **[17]**

As a part of long developing culture, the community is unique in that it a product of a fused Western and Asian culture and a consistent value system yet ‘there is rarely

understanding of the community as a people equipped with an ethnic history'. Similarly, it is often assumed that members of the community suffer from racial self-consciousness and that the practice of "passing" as Europeans has somehow been the preoccupation of the many. The assumption that Anglo-Indians experience or live with a sense of internal conflict or discomfort with their identity and suffer from racial self-consciousness actually overlooks the complex and multifaceted nature of their cultural heritage. The reality of a community deeply rooted in Indian culture and history is contested by the notion that Anglo-Indians have a preoccupation with "passing" as Europeans, is contested by my respondents in Odisha who seem content with who they are.

Accounts of a people stranded in India do not take into account the reality of a people very much belonging to and connected to India. This narrative ignores the experiences of a community that has been a part of the Indian milieu for centuries. This research locates Anglo-Indians in Odisha from the early 1800s thus contesting this popular notion. Furthermore, the belief that Anglo-Indians were simply "lackeys of the British" overlooks the distinct cultural identity of the community and fails to acknowledge that their culture, while influenced by British heritage, is inherently Anglo-Indian.

This chapter analyzes the work of three authors—Glen D'cruz, Dorothy McMenamin, and Megan Stuart Mills—who have focused on the stereotypes surrounding the Anglo-Indian community. Each author examines these stereotypes from different perspectives: D'cruz and McMenamin from within the Anglo-Indian community itself, and Mills as an outsider academic. Together, their work provides a comprehensive framework for understanding the harmful, dehumanizing stereotypes that have plagued Anglo-Indians, particularly those from Odisha, and the ongoing struggles to counteract these stereotypes.

Glen D'cruz and the Anglo-Indian Stereotypes

D'cruz's *Midnight's Orphans* (2006) provides a critical look at the portrayal of Anglo-Indians, particularly at an international reunion where delegates expressed dismay at the way local media perpetuated stereotypes. These stereotypes, especially of Anglo-Indian women as "opportunistic whores," are deeply entrenched in colonial representations and persist in contemporary perceptions. D'cruz quotes Megan Mills, who suggests that dismantling such stereotypes requires scholarly work that uncovers a more nuanced and non-sensationalized reality. This effort is crucial, as stereotypes about Anglo-Indians have often been based on distortions of history and biased cultural assumptions.

In his critique, D'cruz refers to influential works such as Gist and Wright's *Marginality and Identity* (1973), which identifies stereotypes as central to Indian prejudices against Anglo-Indians. He argues that these stereotypes, ranging from portrayals of Anglo-Indians as "mimics" to "half-caste pariahs," have contributed to the creation of an inferiority complex among the community. He also draws on Stuart Hall's idea that stereotyping serves to essentialize and naturalize racial differences, creating social and political boundaries that marginalize non-normative groups. In particular, D'cruz highlights the *Seven Deadly Stereotypes* of Anglo-Indians that recur in colonial and post-colonial discourse:

1. **The Mimic**: Women who attempt to emulate Western ideals of beauty and men who adopt British clothing are viewed as pathetic imitators, creating tensions around their mixed cultural identities.

2. **The Whore**: The stereotype of Anglo-Indian women as morally degenerate temptresses seeking upward mobility through relationships with British men is tied to fears of miscegenation.
3. **The Ditherer**: Anglo-Indian men are depicted as weak, emotionally unstable, and unable to assert themselves in either the British or Indian social contexts.
4. **The Poor Relation**: Anglo-Indians are portrayed as impoverished and dependent, reflecting their marginalization in colonial society.
5. **The Half-Caste Pariah**: Struggling with a conflicted identity, Anglo-Indians are often seen as neither fully Indian nor fully British, leading to a crisis of self and belonging.
6. **The Big Shot**: Those who try to emulate British upper-class manners and customs are labeled as status-hungry and materialistic, obsessed with demonstrating their social superiority.
7. **The Waster**: This figure, often characterized as aimless, unproductive, and prone to self-pity, is seen as morally and socially useless.

D'cruz's work illustrates how these stereotypes have been internalized and perpetuated through colonial literature, academic discourses, and popular culture, reinforcing the marginalization of the Anglo-Indian community.

Dorothy McMenamin and the Social Construction of Stereotypes

Dorothy McMenamin's work offers a more nuanced view of Anglo-Indian stereotypes. In her presentation at the 2010 World Anglo-Indian Reunion in Perth, McMenamin identifies five primary stereotypes associated with Anglo-Indians:

1. **Failure to Capitalize on Education**: The stereotype of Anglo-Indians as lazy and unambitious is juxtaposed with the image of a community that is perceived as fun-loving but unwilling to make the most of educational opportunities.
2. **Lax Morality**: Particularly regarding Anglo-Indian women, McMenamin critiques the view that their lifestyle was morally lax, contrasting how this stereotype is often applied to women but not men.
3. **Social Insularity**: Anglo-Indians are often portrayed as socially isolated, unwilling to mix with other communities. This stereotype highlights the perceived insularity of the group within Indian society.
4. **Railways and Telegraphs**: McMenamin acknowledges the historical reality that many Anglo-Indians were employed in the colonial infrastructure, such as the railways and customs, but she argues that this fact has been used to reinforce their marginal status.
5. **The European Ancestor**: McMenamin points out that Anglo-Indians are often reduced to being seen as the offspring of European men and local women, overlooking the complexities of their identities and heritage

McMenamin critiques the way these stereotypes, while rooted in historical truths, have been applied in ways that demean and degrade the Anglo-Indian community. She also emphasizes that these stereotypes must be understood within the cultural context of Indian society, where colonial legacies and traditional values collide. However, McMenamin believes that some of these stereotypes, such as the perceived failure to utilize education, are fallacious when examined from a historical perspective.

Megan Stuart Mills and the Academic Perspective

Megan Stuart Mills, a non-Anglo-Indian academic, discusses the role of academic institutions and popular media in the ongoing perpetuation of Anglo-Indian stereotypes. Mills argues that stereotypes about Anglo-Indians have not only been historically damaging but continue to be reinforced through biased academic research, sensationalized media portrayals, and everyday social interactions. She categorizes the stereotypes she addresses into eight key points:

1. **Mixed Descent**: The idea that Anglo-Indians are defined solely by their mixed-race heritage oversimplifies their complex identities.
2. **Exclusion Acts**: Mills connects stereotypes about Anglo-Indians to colonial exclusionary policies, which were often shaped by racial biases and led to the marginalization of the community.
3. **Uneducated**: This stereotype paints Anglo-Indians as an undereducated group, reinforcing the belief that they failed to fully integrate into either British or Indian societies.
4. **Passing**: The idea that Anglo-Indians are obsessed with "passing" as European is contested by Mills, who argues that this overlooks the unique cultural identity that many Anglo-Indians embrace.
5. **Lackeys of the British**: Mills critiques the portrayal of Anglo-Indians as mere sycophants of the British, ignoring the complexity of their role in colonial society.
6. **The Abused and Confused**: Anglo-Indians are often portrayed as emotionally and psychologically damaged, struggling with their mixed heritage.
7. **The Frank Anthony Phenomenon**: This refers to the perception of some Anglo-Indians as being overly assimilationist or excessively loyal to British authority.
8. **Inevitable Extinction**: The stereotype that the Anglo-Indian community is dying out or fading into irrelevance is another persistent and damaging myth.

Mills links these stereotypes to broader patterns in post-colonial scholarship, drawing parallels to the "dangerous myths" discussed by McNeill (1986), which often lead to prejudice, exclusion, and a denial of the community's historical and cultural significance. Mills critiques the tendency to ignore the Anglo-Indians' substantial contributions to colonial administration and their role in British South Asia, arguing that their cultural and ethnic identity is often overlooked or misunderstood within the broader narrative of post-colonial studies.

Conclusion: Contesting Stereotypes and Reclaiming Identity

The work of D'cruz, McMenamin, and Mills collectively challenges the stereotypes of Anglo-Indians, offering a more nuanced understanding of the community's identity. They emphasize the importance of recognizing the diversity within the community and the complexity of their cultural heritage. By bringing forward the voices of contemporary Anglo-Indians, especially from Odisha, this research attempts to correct the misrepresentations in both colonial and post-colonial narratives. The community, far from being marginalized and "in between" British and Indian worlds, has a unique identity that

is deeply connected to Indian history and culture, and this identity deserves to be acknowledged and celebrated.

D'cruz's Seven Deadly Stereotypes, McMenamin's nuanced critique of historical realities, and Mills's academic analysis of the social and cultural forces that perpetuate these stereotypes provide the foundation for this corrective project. Through a careful examination of the lived experiences of Anglo-Indians in Odisha, this research seeks to challenge the reductive portrayals of Anglo-Indians as "outsiders" and "failures," promoting a more authentic and multifaceted understanding of their place in Indian society.

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An adoptive technique to implement steganography on digital image using integer wavelet transform domain

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Abstract: -

Now a day's data transfer over internet is the main problem. Information security is one of the possible areas of research in present days, The data needs to be secure. So that it could be achieved by only authorized user. So that the data needs to be sent in a secure way which the receiver should be able to understand the message. In information hiding, cryptography and steganography are the most widely used areas that come to mind for sending sensitive and private information in a secured manner. The limitation of cryptography was that other person came to know that the probability of message being decoded by another person. Cryptography change the structure of the hidden message and steganography doesn't change the structure of the hidden message. To overcome this limitation, we use a technique is called steganography. Steganography means secret writing. It means hiding secret information in specific carrier data. The steganography plays an important role to hide data in such media which is audio, video, text, image etc. This paper implements image steganography with an objective of improve security and allocating maximum amount of data to be hidden inside. To achieve this initially cover image is transformed from spatial domain to frequency domain using 2D wavelet transformed image allowing embedding inside high frequency region which maintains image quality. In this paper we applying 2D HAAR technique in cover image for decomposition and Huffman encoding technique for embedding the secret message and use a encryption key for better security. In existing paper there are used dwt technique but there are some problem. So in this paper we use IWT for hiding secret data using some algorithm and calculate the signal to noise ratio and mean square error.

Index Terms- Spatial domain, Frequency domain ; HAAR Technique; Huffman encoding ;DWT; IWT; SNR ; MSE; Steganography.

1. Introduction

The usage of the Internet for data transfers is expanding quickly in the modern world because it is both quicker and easier to get data to its destination. The internet is therefore used by many individuals and businesspeople to transmit essential information and business papers. Since any unauthorized person might hack data and render it useless or gain information that is not intended for him, security is a crucial consideration when exchanging data via the internet. The most popular fields that spring to mind when discussing information concealment are steganography and cryptography, which allow

for the secure transmission of private and sensitive data. The other person was cryptography's constraint. The cryptography method is a widely used technique for protecting sensitive data over the Internet. In this method the data take a form in such a way that it becomes hard to recognize the original form except the intended recipient. But as the coded data are in unrecognized form, it encourages the opponent to attack. Avoiding the suspicion of the information inside the carrier. Higher security is offered by the suggested method, which can also safeguard the message. The technique known as "steganography" refers to covered writing. It's a Greek term. Covered means stegano, and writing means graphy. The Steganography is a technique which means writing a secret message which a way no one can found that there is a hidden message. There are many different carriers that can be used to hide the information such as digital images, videos, sound files and other computer files but digital images are the most popular.

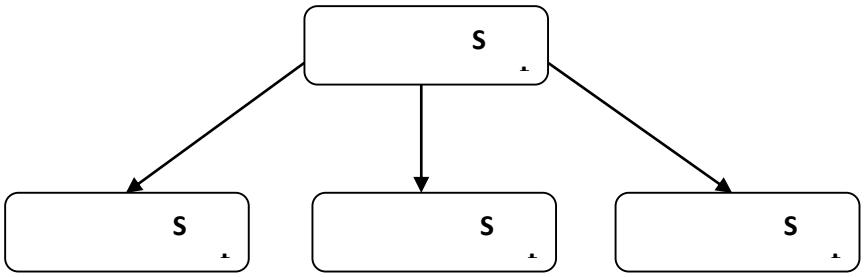

Figure 1.:- Steganography Domains

According to type of embedding domain Stegano graphy in image is divided in spatial domain and transform domain. In spatial domain technique the real picture space is directly alter the position, It is a method in which information hiding is performed directly value of the pixel of the cover image. The effect of messages which is noticeable on the cover image . In transform domain, techniques are based on modifying the Fourier transform of an image the initial step is to transform the cover image into another domain. The transformed coefficients which is used for hide secret message. These changed coefficients are transformed back into spatial domain to get the stego image. The main problem is that it a lossless technique and the additive noise quantity which can be steals in the Transform domain methods are more benefit than spatial domain method if it used for hiding the information in the area of image which is a lesser quantity of expose in compressing, cropping and also image processing. Transform domain method which don't appear in the image and which is exceed lossless and lossy translations.

Most of the stenographic systems recognized now a days which is essentially work on some method of transform domain. These techniques is used to hide information which is important parts of the cover image. It make them extra strong to occurrences, One process is to use the Fourier and cosine transforms such as Discrete Fourier Transform (DFT)or Discrete Cosine Transform (DCT) to embed the information in the images. Another is the use of wavelet transforms such as Discrete Wavelet Transform (DWT) or Integer Wavelet Transform (IWT). We have used Integer Wavelet Transform in our proposed method. In this paper, initially some steganography methods are analyzed. The main intention is to devise a steganography technique so that it can provide better security than some existing techniques.

2. Related Work

A. DWT Based:-

The Discrete Wavelet Transform (DWT) is a comparatively test and organized method in computer science. Wavelet study is useful as it achieves local breakdown and multi resolution study. Study of a signal in various frequency with altered resolutions is known as multi-resolution analysis (MRA). This technique transforms the purpose in wavelet area, processes the coefficient and then achieves inverse wavelet transform to represent the original format of the stego object. Discrete Wavelet Transform can recognize portions of cover image where secret data could be excellently hidden. DWT splitting data into high and low frequency components. Specifics regarding the edge mechanisms are covered by the high frequency portion of the signal, while the low frequency portion includes the majority of the image's signal information, which is again separated into higher and lower frequency sections. The initial DWT is applied in the vertical direction while being observed in the horizontal direction for every degree of decomposition in two-dimensional applications.

B. IWT Based:-

The planned algorithm works in the wavelet transform coefficients in which the message is embedded into the four sub band of two dimensional wavelet transform. Those problems of floating point accuracy are ignored of the wavelet filters, we used the technique Integer Wavelet Transform. It gives better result as compare to dwt technique. IWT performs to become a nearer copy with compact scale of the original picture in LL sub band. When the LL sub band of DWT is inaccurate, the IWT procedure are achieves.

C. Advantages of IWT over DWT:-

Typically, wavelet domain enables us to conceal the data. The HVS, or human visual system, is not as sensitive. To conceal the data, high resolution detail bands like HL, LH, and HH are utilized. In some areas, data concealing enables robustness and produces good visual quality. IWT converts one set of integer data into another. Wavelet filters with floating point coefficients are used in DWT. Any truncation of an integer pixel's floating point value causes the hidden data to be lost when we conceal it in its coefficients, which could result in the data hiding mechanism failing.

The wavelet transform maps integer to integer. In case of DWT if the input is integer then the resulting output is no longer consist of integers so the perfect reconstruction of the original image become difficult. In that reason we use IWT technique instead of DWT. In IWT technique it increases hiding capacity of the system as compare to DWT. In the proposed method we have used discrete wavelet transformation for converting image from its spatial domain to frequency domain.

In the proposed method we have used discrete Wavelet transformation for converting image from its spatial domain to frequency domain. A wavelet which start in zero and return back to zeros .it is called wave like oscillation..Unlike the Fourier transform, which only construct a frequency demonstration of signal is constructed by Fourier transform the wavelet transform is able to construct a time-frequency representation of a signal simultaneously. The main purpose of converting an image into frequency domain during steganography is that when we insert our secret information into frequency domain it is very difficult to detect steganography. Indiscrete wavelet transformation for images we separate the high freq. and low freq. information. Low freq info are encompasses information about the smoother places of the image and it is very sensitive information where slight modification affects the reconstructed (Stegoimage) image. On the other hand high freq data are contains the information of the edge, corner etc of a picture. Hence

modification in this information results less noise in the reconstructed image. The data whose length is a integer and a power of two and the difference of the vector is also same length, there we works discrete wavelet transform. It is a implement which split up information into various frequency mechanisms, and then evaluating every element with determination exactly matched to its scale.

DWT is calculated with a force of filters monitored by a factor2substituteSampling. The DWT can also be orthogonal and is invertible.This suggested approach makes use of the Haar wavelet processing. The mathematician Alfrd Haarin made the proposal in 1909.A discrete signal was split into a high subband and a low subband at each level using the Haar wavelet transform, which separated the signals by half of their length. In the first level, the low subband is broken down. When converting a signal from the spatial to the frequency domain and vice versa, the Wavelet transform is one of the most advanced transformations available. A second generation of transforms includes the Wavelet transform and several related transforms. Wavelets are brief wave oscillations that diminish quickly over time.

Additionally, they offer a vast array of applications that can be used in a variety of domains, including speech recognition, image de-noising, fingerprint verification, picture processing, data compression, and signal processing. It has been reported that the steganography technology can make use of the Wavelet transform to boost its durability and capacity. The "Haar" Wavelet transform family is one that has been used in this case. It applies operations in the horizontal and vertical directions to transform an image from the spatial domain to the frequency domain.

D. 2d-Haar-Wavelet transform:-

The wavelet transform can concurrently propose many data points in the frequency-time domain. The 2D HAAR wavelet transform removes high and low frequencies by delivering the time domain over high-pass and low-pass filters, respectively. Each time a segment of the signal wears out, this method is repeated repeatedly. Using discrete wavelet transform analysis, signals are divided into two classes: low sub-band and high sub-band. Signal decomposition for various scales and frequency ranges. Two function sets that are associated with low and high pass filters in an ordered fashion are used Decomposition proceeds in the same way as time separability. For example, frequency separability is doubled when only half of the samples in a signal are adequate to represent the entire signal. The Haar wavelet works with data that is calculated by adding and subtracting neighboring elements. The wavelet first affected neighboring horizontal components before moving on to adjacent vertical elements. The resemblance to the inverse is a fundamental characteristic of the Haar wavelet transform. The data energy in the upper left corner is calculated for each transformation.

E. Huffman Encoding Technique:-

Huffman code is mostly used technique for data compression. Huffman algorithm applies greedy approach that considers the occurrence of each character and delivers an optimal string of binary letters. Huffman coding techniques is used for decreasing the amount of bits required to symbolize string of symbols. It is a variable length code that assigns short length codes to frequently used symbols, and long length codes to the symbols appearing less frequently. Huffman codes are optimal codes that map one symbol to one code word. For image compression, Huffman coding assigns a binary code to every pixel intensity value and a two Dimensional (2D) pxq image is converted to a one dimensional (1D) bits stream with length less than pxq. Huffman Encoding is applied to secret object (image/text)

and then each bit of Huffman code of secret object (image/text)is embedded inside the cover image.

3. Proposed Methodology

A distinctive feature of proposed system is that it allows user to select any image as cover image from the database of images formed which are a smaller amount of susceptible to steganalysis attacks. Here big size images are collected in the database in order to store as much data as possible inside the image. The block diagram of proposed steganographic system is given in figure 2 The proposed method contains the embedding phase.

A. Embedding Phase

Embedding is the process of hiding the secret image inside a cover image there by generating a stego image. It involves hiding secret image inside an image selected from the database of images by combining IWT, Huffman coding combined to form a stego-image The algorithm for the embedding data.

Embedding Algorithm

Inputs: Secret Data (D), Cover Image(C)

Output: Stego image(S) with secret data embedded in it.

i. Apply Huffman encoding technique in the Secret Image.

ii. Decomposed the cover image into 4 non over lapping sub bands. These are LL (Approximation coefficients).LH(Vertical details). HL (Horizontal details) and HH (Diagonal details).

iii. The division of the planes is done by employing HAAR filters.

iv. Information contains in the LL sub bands of secret images is separately embedded into different bands of cover image.

v. Apply logistic chaotic map in the embedded output

vi. After embedding the secret image bit into the cover image inverse transformation is performed to retrieve them.

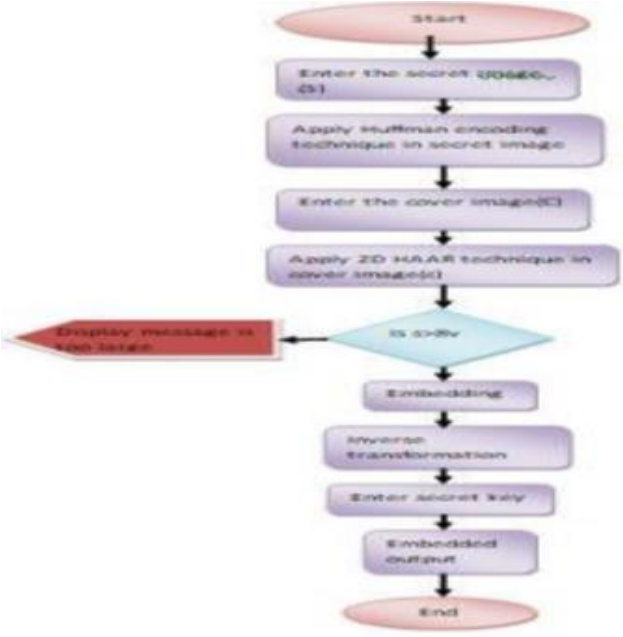

Figure.2:- Flow Chart of Embedding Process

4. Result Analysis

This section provides the experimental results and analysis of the proposed scheme. This work is simulated using MATLAB2014a with the system specification-window 10 os, Intel i3 core processor and 64bit operating system. We take a 8 bit grey image. Then apply DWT method and find out the snr and mse of the decomposition image. Then apply the IWT method and compare the result. Fig:3 show the Cover Image & Secret image of DWT & IWT. Fig 4 show the embedded output of both technique And Fig 5 show the histogram result.

Figure.3:- CoverImage1, CoverImage2, CoverImage3, SecretImage1, SecretImage2, SecretImage3

Embedded output

For DWT

For IWT

Histogram Result

For DWT

For IWT

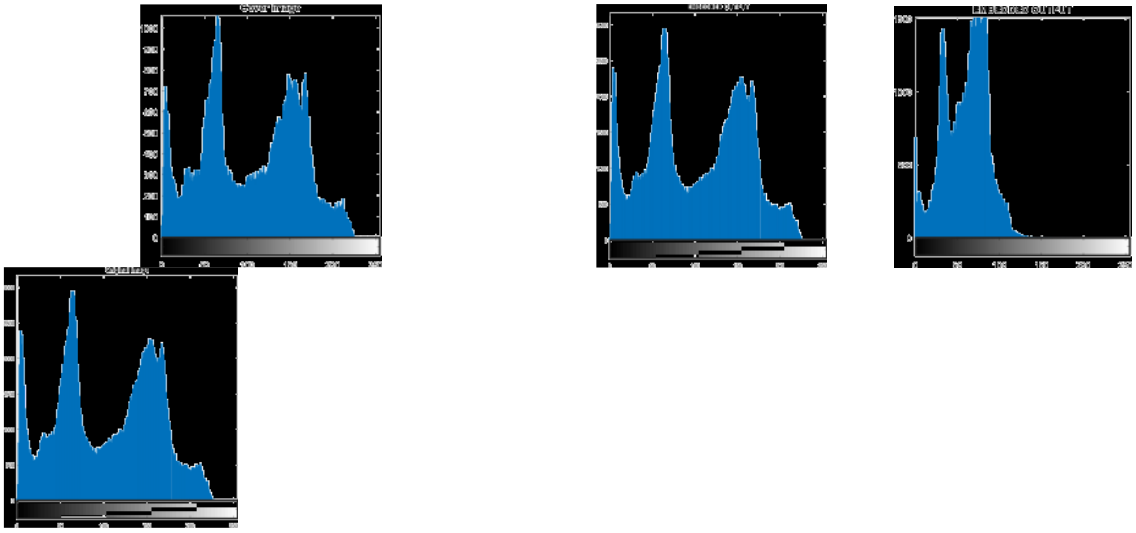

Figure.4:- 1) Embedded output and 2) Histogram Result

Figure shows that there are a very little changes between the structures of histograms of cover images and stego images. Hence the cover image and stego image accomplishes better noiselessness. Another factor to be considered is Signal to Noise Ratio (SNR). SNR is measure to image quality. Table 1 shows the SNR and MSE obtained from the proposed method. A steganographic system requires high SNR value which shows low difference between cover image and stego image. The measurement of the quality between the cover image and stego-image is defined by SNR as:

$$\text{SNR= DB } 10\log\frac{255}{MSE}$$

Comparison Table of SNR & MSE of DWT & IWT

		DWT		**IWT**	
Sl. No.	**Secret Image**	**SNR**	**MSE**	**SNR**	**MSE**
1	1	27.87	8.33	29.03	8.26
2	2	28.71	6.18	31.13	6
3	3	26.96	7.79	27.8	7.71

6. Conclusion

Steganography is a technique which is used for secretly writing the messages in such a way that no one can retrieve from the sender and receiver. In this paper we study on various steganographic method and design a steganographic method using integer wavelet transform domain in order to increase the embedding capacity DWT and IWT method is successfully implemented and result are delivered. Compare the DWT technique with IWT and generate a key using logistic chaotic map for improving the hiding capacity. In near future we extract the secret image from the embedded output using the algorithm.

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Manufacturing of Fine Aggregate for Making Concrete from Fine Sand, Quarry dust and Fly ash

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Abstract

This study focuses on improving the economy of concrete by replacing natural sand with artificial fine aggregates. Various combinations of sand, fly ash, and quarry dust (all below 4.75 mm) were tested to determine their effect on compressive strength. Results show that replacing 40% to 50% of natural fine aggregate with artificial fine aggregates enhances compressive strength, depending on the material composition. By blending different types of fine aggregates in varying proportions, this research aims to achieve the desired compressive strength in concrete.

Keywords: Sand, Artificial fine aggregate, Crushed stone, quarry dust, Compressive strength

1. Introduction

India's growing infrastructure needs, driven by globalization, have increased the demand for concrete in projects like highways, power plants, and industrial structures. Advances in concrete technology have improved its strength and economy, but the reliance on natural sand, a key ingredient, has led to scarcity and high costs. The excessive quarrying of river sand to meet construction demands has caused environmental issues, including depletion of sand resources, reduced groundwater levels, land erosion, and harm to local flora and fauna. This highlights the urgent need for sustainable alternatives to natural sand.

Artificial fine aggregate, made from fine sand, fly ash, and quarry dust (passing through a 425-micron sieve), offers a cost-effective and impurity-free alternative to natural sand. Its use addresses technical, commercial, and environmental concerns, making it a viable substitute. Various tests were conducted to evaluate its performance, and concrete produced with different grades of artificial fine aggregate was compared to conventional concrete, showcasing its potential as an effective replacement.

2. Materials and Methods

2.1 Materials

2.1.1 Fly ash: Fly ash is a finely divided residue produced from the combustion of pulverized coal in coal-fired power plants, with over 61 million metric tons generated daily. During combustion, coal ignites in the boiler's chamber, creating heat and leaving behind molten mineral residue. Coarse particles, known as bottom ash or slag, settle at the bottom, while lighter particles, called fly ash, remain suspended in the flue gas. Annually, over 20 million metric tons of fly ash are utilized in various engineering applications, including the production of artificial coarse aggregate, providing an effective use for this industrial by product.

2.1.2 Quarry dust: Quarry dust, a by-product of the crushing process during quarrying, is a viable alternative to sand in construction projects. It can replace sand wholly or partially to produce quarry dust concrete, which is believed to be stronger and more durable than conventional concrete. The scarcity of sand and the need to reduce construction costs have driven the search for alternative materials like quarry dust, which offers comparable strength, with or without concrete admixtures, making it an efficient substitute in construction.

2.1.3 Fine sand: This is the sand particle below the size of 425 micron. It is very fine and includes a high amount of silt & clay. In regular use the particle size we needed is of 600 micron & above upto 2.36mm size. The extra fines are mainly used as filling & leveling of the road, foundation filling etc.

2.1.3.1 Bulking of fine aggregate:

The increase in the volume of sand due to moisture content is known as bulking of sand. A thin film of water forms around the sand particles, causing them to push apart and increase in volume. Bulking depends on the moisture content and the size of the particles, with finer sand experiencing greater bulking compared to coarser sand. Moisture levels of 5% to 8% can increase the volume of sand by 20% to 40%.

When more water is added, the film around the sand particles breaks, causing the particles to pack closer together and reducing the bulking. Dry sand and fully saturated sand have the same volume. This principle is utilized to measure the percentage of bulking in a sand sample.

2.1.3.2 Specific gravity:

Specific gravity is the ratio of the density or mass of a substance to a reference substance at a fixed temperature, with both having the same volume. For fine aggregate sand, it is calculated similarly, comparing the density or mass of the sand to that of the reference substance while keeping the volume constant.

Standard Value of Specific Gravity of Sand

The specific gravity of sand typically averages around 2.65, with values for road construction materials ranging from 2.5 to 3.0 and an average of 2.68, primarily due to quartz, which has a specific gravity of 2.65 to 2.67. Inorganic clays generally range from 2.70 to 2.80, while soils with high organic content or porous particles have lower specific gravities, sometimes as low as 2.00. Tropical iron-rich laterite and certain lateritic soils often have specific gravities between 2.75 and 3.0, occasionally higher. Water absorption

for these materials should not exceed 0.6% by weight.

2.2 Methodology

2.2.1 Testing of the Materials

As we were adding cement to the material for the trial phase we kept the material wet for 7 days of curing to gain its 95% of initial strength. Materials with different combinations of materials are considered and tested. The following combinations of materials are considered.

There was 5 kind of material mix was adopted for tests as follows: 1. Natural sand + cement (S1), 2. sand + fly ash + quarry dust + cement(S2), 3. Sand + quarry dust + cement (S3), 4. fly ash + cement (S4) 5. Quarry dust + cement(S5). S4 & S5 material was disqualified for further manufacturing as the bond between the materials was not so strong enough.

3. Results and discussion

3.1 Various test results of the Fine aggregate:

Table 1. Various test results of the Fine aggregate has been presented in Table –1.

Sample No	Ratio of Ingredien/ cement	Water Cement Ratio	Test Results of Materials				
			Particle size distribution	Bulking of F.A.	Specific gravity	Water Absorption	Consistency of Cement
S1	3:1	15.62 %	Zone 2	Coarse Grained	2.445	10%	34
S2	1:1:1:1	23 %	Zone 1	Coarse Grained	2.446	10%	
S3	1.5:1.5:1	13.12 %	Zone 2	Coarse Grained	2.467	15%	

Note:

1. Above percentage we got from 400 gm of material from each
2. From the above data it concludes that the materials have water absorption capacity below 60% hence it can be used.
3. Water Cement ratio stated above are for the test for compressive test of fine aggregate

3.2 Compressive Strength of Mortar with artificial fine aggregate

Compressive strength refers to the ability of a material or structure to resist or withstand compression. It is determined by the material's capacity to prevent failure, such as cracks and fissures, under pressure. In testing, an impact force is applied to both faces of a mortar specimen made with cement, and the maximum compression the specimen can endure without failure is recorded. Specifically, the compressive strength of cement is the ability of a cement specimen to resist compressive stress when tested under a Universal Testing Machine (UTM) at 28 days.

3.2.1 Test data of mortar cube for Dust and Sand

Table 2. Compressive test of mortar with artificial Fine aggregate is presented in Table 2

Sample type	7 day's Compressive strength (Artificial FA)			28 day's Compressive strength (Artificial FA)		
Sample No	1	2	3	1	2	3
S1+cement	10.5	10.9	10.1	30.1	33.6	34.8
S2+cement	10.4	10.8	10.6	32.3	33.8	34.4
S2+cement+sand	10.8	10.7	11	31.8	33.8	34.91
S2+cement+sand+quarry dust	10.2	10.68	10.96	33.67	34.3	34.45

3.3 Compressive test of mortar with natural sand

Table 3. The compressive stress obtained by the natural sand has been presented in Table -3

Sample type	Compressive strength in mpa
S0	40.97
S1	34.8
S2	34.91
S3	35

The sample S1, S2 is attained the compressive stress below to that of the natural sand, as the compressive strength of natural sand 40.97 mpa & of other material 34.8mpa, 34.91mpa, 35 mpa respectively.

3.4 Compressive strength of concrete

Table 4. Compressive strength of concrete has been presented in Table -4

	Compressive strength of concrete					
	At 7 days			At 28 days		
Sample	1	2	3	1	2	3
S0	6.6	6.9	6.7	18.7	19.3	19.9
S1	8.4	8.9	8.1	21.2	21.6	21.3
S2	7.6	8.2	8.6	21.7	21.4	21.7
S3	8.1	8.7	9.8	21.6	21.9	22

The highest compressive stress attained by the materials, 21.6mpa,21.6mpa, 21.9mpa are much higher than that of natural sand of 19.9mpa. Hence it can be used as concrete. From the above data it concludes that the materials have water absorption capacity below 60% hence it can be used. From the analysis it concludes that the S1 & S3 is under the category zone II & the S2 is under Zone I. It concluded that the all the samples of S1,S2,S3 are coarse grained fine aggregate. Consistency of the cement 34. Performance of cement mortar is lower than the natural sand as it attained more than the artificial sand. The highest compressive stress attained by the material, 21.6mpa,21.7mpa, 21.9mpa are much higher than that of natural sand of 19.9mpa. Hence it can be used as concrete. All the materials can be used in Mass concrete foundation without vibration.

4. Conclusion

Various experimental studies have been conducted by researchers to examine operational parameters such as workability and compressive strength when replacing natural sand with artificial sand. These studies show that concrete made with artificial sand performs better than that made with natural sand due to the superior properties of artificial sand. It has been concluded that different types of artificial sand yield varying results for compressive strength, depending on the quarry source. Research indicates that replacing 40% to 50% of natural sand with artificial sand results in the maximum compressive strength.

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ML Classifier with Hyperparameter Optimisation Based Cardiovascular Disease Prognosis

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Abstract

In present scenario, heart disease is gradually becoming a common disease irrespective of age due to several factors and prognosis of cardio vascular disease is a challenging task in health care sector. Machine learning techniques have been used by many researchers for health care data analysis and forecasting of patient's risk. But we have used Light Gradient Boosting Machine (LightGBM) classifier to forecast patient's risk of heart failure. Eventually, the hyperparameters are tuned to increase efficiency of the classifier for better classification accuracy. Class imbalances in the dataset (available at UCI machine learning repository) are resolved using Synthetic Minority Oversampling Technique (SMOTE). The results show 95% accuracy cap and 95% recall rate while precision rate is 94%. Moreover, our model presents 95% of F-score which leads to predict patient's heart failure more precisely. This prediction may be helpful to treating cardiologist in the diagnosis of cardio vascular disease to save the human life much before cardiac arrest.

Keywords: Cardiovascular disease, Prognosis, Hyperparameter, LightGBM Classifier, Accuracy, Health care

1. Introduction

Now a day irrational living life affects the heart and blood vessels for which Neuro-genetic, Diabetics, Carcinoma, Cardiovascular, Psoriasis types of liver diseases are coming into picture. Cardiovascular disease is one of the diseases in which premature deaths are in high rate as per medical data. The World Health Organization estimates that 1/5 of these global deaths occur in India. Age-standard cardiovascular death is reported by the Global Burden of Disease study. Cardiovascular disease is the leading cause of death worldwide, killing about 18 million people annually, with India having a rate of 272 per 100,000 people, higher than the global average of 235. This is roughly 30% of all fatalities worldwide. Heart attacks and strokes are responsible for more than 80% of deaths from cardiovascular disease, and 70% of those deaths happen before the age of 60. Cardiovascular disease is a major cause of heart failure, and this dataset contains 11 traits that can be used to predict the development of heart disease.

The term "CVD (Cardio Vascular Disease)" refers to a number of conditions affecting the heart and circulatory system that present as different pathologies like stroke, heart

failure, or coronary disease. Heart failure is a pathophysiological condition in which the heart is unable to expel blood (unable to perform adequately). Heart rate (HR) can be classified according to the heart's ability to expel blood from the ventricles. Ejection Fraction (EF) is the percentage of the volume of blood expelled from the ventricle during systole and is determined by dividing the stroke volume by the end-diastolic volume. The ventricles typically constrict during systole and release 60 to 80% of the blood they hold by the end of diastole. Systolic or diastolic dysfunction may be the cause of heart failure. By identifying trends in the data it receives from the past and basing its predictions on those trends, computers can learn on their own through a process known as machine learning. This is the best method for identifying diseases because it can tell whether a patient has a CVD or not by looking at a number of crucial metrics. Several machine learning algorithms have been applied till now to different kinds of diseases. In this paper, the LightGBM Algorithm has been implemented for the detection of the risks of heart diseases.

2. Literature Review

Literature review presents a brief discussion on the research and implementation carried out by different authors across globe to predict heart failure using machine learning algorithms efficiently.

The proposed work [1] uses One-Hot coding to optimize eXtreme Gradient BOOSTing (XGBoost) and five different assessment metrics: precision, sensitivity, specificity, F1 score, and Area Under the ROC curve (AUC) of the Receiver Operating Characteristic (ROC) charts. It also uses Bayesian optimization as a hyperparameter optimization technique which has proven to be a very accurate method for obtaining the best hyperparameters.

The authors in [2], are able to accurately assess and stratify the risk of heart failure of the patients using the XGBoost algorithm. It uses the GridSearchCv to select the parameters with maximum accuracy. It also uses SHapley Additive exPlanations (SHAP) values that explicitly explained key features that influenced the model’s result. It helps treating physicians to understand why people suffer from heart failure.

The analysis have been carried out on 299 heart failure patients in 2015. 299 patients with heart failure underwent the analysis in 2015. The authors in [3] have also used conventional biostatistical tests to classify alternative traits, and they compared the outcomes to those of the algorithm.

To assess survival predictive performance using gender-specific informative risk factors for patients with left ventricular systolic dysfunction is studied in [4]. The authors have concluded that the predictive model for women differs significantly from that for men. Platelet count, while for men smoking, diabetes, and anemia with zero regression coefficients are not meaningful.

In order to maximise the effectiveness of the random forest classifier and the XGBoost classifier model, the documentation relies on hyperparameter optimisation using randomised search, grid search, and genetic programming [5]. These two models' performance have been compared to that of prior research.

The objective of [6] is based primarily on optimistic express assumptions and represented

one of three hard and fast visions of the future for population fitness. Based on data from 1990, the authors have made predictions. Even though they are very out of date, they anticipated the spread of HIV/AIDS. Making public-fitness officers plan future regulations to reduce the burden of disease and deaths globally are the authors' main objective.

The authors of [7] have created a hybrid genetic-fuzzy coronary heart disorder analysis tool. The suggested version, known as the GAFL (Genetic Algorithm Fuzzy Logic) version, produces an accurate prediction of coronary heart disease. Because it was simple to construct, the authors' main objective became to provide resources to doctors working in hospitals and other clinical settings.

In this article [8], the authors have developed a PSO-optimized multi-layered perceptual artificial neural network and applied the Fast Correlation Based Feature Selection (FCBF) method to remove redundant features and enhance the classification of heart diseases. The proposed model's mixed strategy is applied to the heart disease data set. The model later produced a 99% accuracy rate.

The authors of the article [9] demonstrate how effectively artificial intelligence techniques are used in medical diagnostic tools to improve diagnostic accuracy and give doctors access to more information about. Taking about 500 patients with 23 characteristics in the data set into consideration, it outputs with a 79% accuracy rate.

The SMOTE oversampling algorithm, which has been created to address the imbalance in data sets, was described in the article [10]. In order to improve the performance of the classifier in the ROC space, this method performs oversampling in the minority class and subsampling in the majority class.

3. Objective

The objective of our effort is illustrated lucidly for better understanding of the readers across the globe. In this section, the paper's goals are clearly described.

i. The main objective of the paper is to demonstrate the importance of data pre-processing in raising a machine learning model's general performance.
ii. This paper aims to predict whether or not someone will suffer from heart disease or not more accurately than the already present methods. Based on numerous features like age, sex, chest pain, resting blood pressure, cholesterol, etc. the results are predicted for cardiologists for better treatment.
iii. This paper additionally exploits the overall performance of different algorithms and compares them with the proposed algorithm or model, which includes linear regression, K- Nearest Neighbours (KNN), random forests, support vector machines (SVM), and XGBoost.
iv. Finally, SHAP values are used to interpret the received results in order to assess the effect of every feature on the prediction.

5. Proposed model and Methodology

Many researchers have suggested many methodologies for forecasting of cardiovascular diseases and precautions that have helped treating physicians to save the life of patients globally. But LightGBM model is suggested in our work for estimating the likelihood that a patient will suffer heart diseases. An open-source library called LightGBM offers a more effective and precise implementation of gradient boosting algorithms. It is an entire, distributed gradient boosting framework with high overall performance that is entirely based on decision tree algorithms. These are employed in a variety of system learning tasks, including ranking and classification [11–13].

The hyper parameters of LightGBM are tuned in this paper, and it is discovered that the tuning resulted in a higher accuracy rating. Positive overall performance metrics have been used to analyse the overall performance of the proposed model. Maximum accuracy rate for the results is 94.69%. Furthermore, the proposed model indicates a most F-score value of 94.75% and a precision of 93.74%. The outcomes of this technique are as compared with numerous present algorithms which include Linear Regression, KNN, Random Forests, and XGBoost, is found that the accuracy of LightGBM with tuned hyperparameter outperformed them in terms of accuracy, precision, and F-score values. As a result, the proposed model can more accurately predict the risk of patients who could develop heart diseases.

LightGBM models require extra knowledge and tuning than Random Forest and Support Vector Machines techniques. It is nearly seven times quicker than XGBoost and is a far better method when the datasets are huge. This library is mainly focused on computational speed and model's performance; as such there are few frills. The implementation of the set of rules turned into the performance of computing time and memory resources.

In this work, the layout goal is to make quality use of to be had assets to teach the model. The gradient boosting decision tree algorithm is implemented by LightGBM. LightGBM basically operates on the tabular data, with the rows representing observations, one column representing the goal variable or label, while the final columns are representing features.

We undergo cycles that again and again construct new models and integrate them into an ensemble model. We begin the cycle with the means of calculating the error for every observation of the dataset. Then we construct a new model to predict the results. The predictions are uploaded from the model to the "ensemble of models". All the predictions are now uploaded in the preceding order to make the prediction. Those predictions can be used to calculate the new errors, and construct a subsequent model and then upload them to the ensemble. A few base predictions are needed to begin the cycle. Even if its predictions are very inaccurate, the next additions to the ensemble will deal with the errors.

LightGBM has some parameters which could affect our model's accuracy and training speed. The parameters altered on this model are learning rate, min child weight, gamma,

subsample, collected sample by tree, and max depth. These parameters were altered using the iterative randomized search which tried all the permutations and combinations and selected the values which resulted in the maximum accuracy.

This work is very much focused on data pre-processing as it plays a very vital role in developing an efficient model. The null and categorical values were mainly taken care of in this process. For the starters, the null values are filled with the median of the other values present in that column. Then, the features including gender, ever married, and residence type are converted into integer values from string values using the map function. Due to the presence of class imbalance, SMOTE is used to create an over-sample of the minority class. This drastically increases the accuracy of the model. The dataset is now divided into parts- Training data and testing data using a sci-kitlearn tool, train_test_split. The dataset is split in this kind of manner that the training data and testing data include 80% and 20% of the dataset respectively. The model is now trained using the LightGBM classifier. To obtain the maximum accuracy, a set of grid parameters are considered for the LightGBM. The iterative randomised search, which applied all permutations and combinations that resulted in the maximum accuracy, are used to extract the best value combinations from the grid. The model is now being trained using these obtained values. The name of this technique is hyperparameter tuning. The results are then obtained by comparing the trained model to the testing data. Figure 1 shows a diagram that illustrates this process.

5. Results and Analysis

The outcomes of using the LightGBM classifier have been discussed in this section. The outcomes are contrasted against those of other techniques like Logistic Regression, KNN, SVM, and XGBoost. The model has been trained and tested on a dataset with 5000 (approx.) cases. On testing the model against the training data, the LightGBM classifier trained model resulted in an accuracy of 94.95%. The recall, precision, and F-score were 95.88%, 94.13%, and 94.99% respectively. In Figure 2, the performance is represented under the ROC (receiver-operating characteristic) curve. The results are further compared with the results obtained from other methods. It is found that the LightGBM outperformed the other methods in terms of accuracy including Logistic Regression (LR), KNN, Random Forests (RF), and XGBoost which are found to be 79.25%, 82.61%, 86.27%, and 90.91% respectively. The comparison is shown in Figure 3.

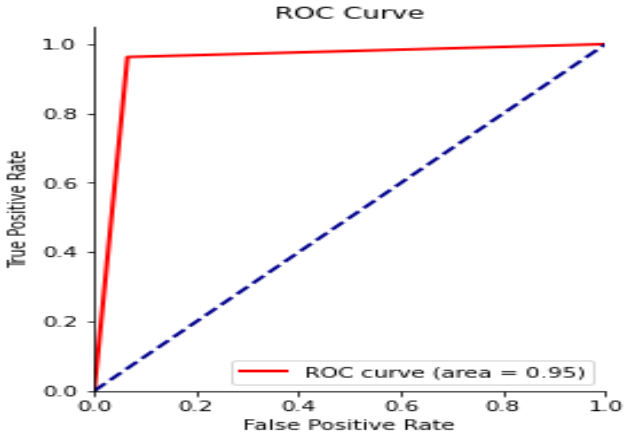

Figure-1. ROC curve representing TPR (true positive rate) vs FPR (false positive rate)

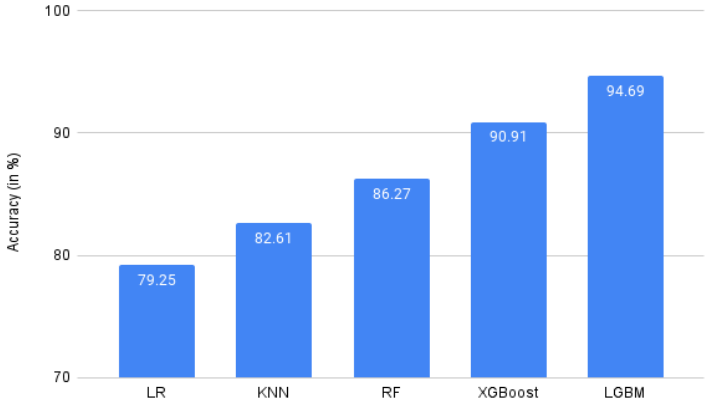

Figure-2. Comparative analysis of the accuracy of LightGBM with other algorithms

We also chose the functions that have an impact on the outcomes of using SHAP values. Figure 4 depicts all kinds of features through the sum of SHAP value magnitudes over all samples. It is observed that the patients who suffered from heart diseases show features like higher age, had smoking habits, avg. glucose levels, gender, and work type. The red colour represents a high value and the blue colour represents a low value.

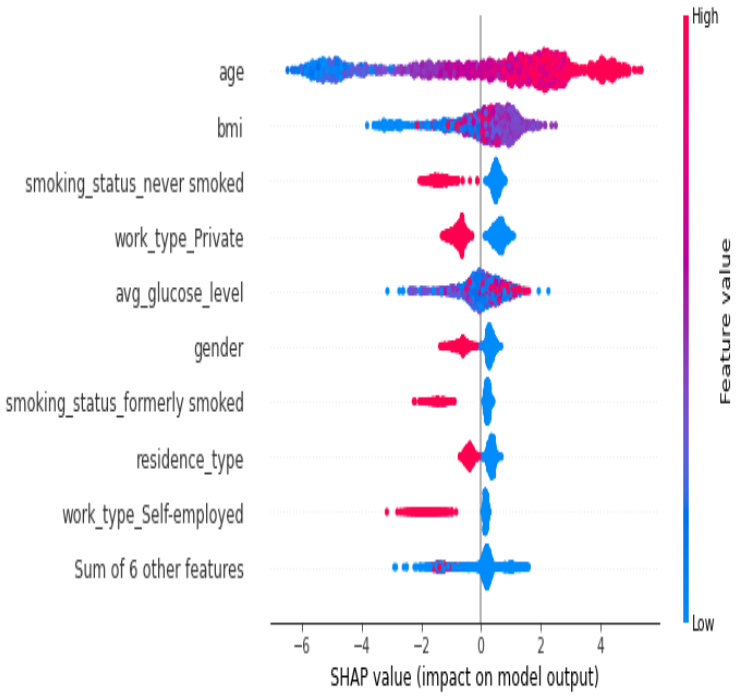

Figure-3: Impacts of each feature on the output model

The contribution of every feature is explained in the Figure 5. The figure demonstrates the contribution of the features in the output given by the model. Features that tend the prediction to class 1(i.e., Heart Disease) are represented in red colour while the features tending the prediction to class 0 (i.e., no Heart Disease) are represented in blue.

Figure-4. Contribution of each feature in the model results

5. Conclusion

Heart/cardiovascular disease is a leading cause of death each year. The goal of this paper is to estimate the likelihood that patients will experience heart disease most frequently. We have concentrated on the imbalance in the dataset, a very prevalent issue, in order to improve the model's efficacy. It is found that using SMOTE significantly improved the model's accuracy. By tuning the hyperparameters of the LightGBM classifier, we have obtained an accuracy of 94.69% (~95% approx.). The global and local SHAP values are calculated to explain how each feature affects the model as well as how each patient's symptoms contributed to the diagnosis for that patient. From the SHAP value, it can conclude that: Older patients are more at risk of having cardiovascular disease. Patients with low BMI scores are less likely to suffer from cardiovascular diseases. Patients with smoking habits are at a higher risk to suffer from cardiovascular diseases. High Avg. glucose level also increases the risk of cardiovascular disease. At the same time males are more likely to have cardiovascular disease than females. Self-employed patients are less likely to suffer from cardiovascular diseases.

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Modelling and Forecasting of Erosive Behaviour in SiC-Added Bio-Fiber Composites by Taguchi Optimization & Neural Network Techniques

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Abstract

This research emphasises on the erosive wear performance of epoxy composites reinforced with short fibers sourced from the waste scales of freshwater fish and enhanced with silicon carbide (SiC). The erosion behavior is studied using an air jet erosion test apparatus, applying Taguchi's design-of-experiment technique. The results highlight SiC as an effective filler, significantly improving the composite's resistance to erosive wear. Key factors influencing the erosion rate include SiC content, impingement angle, and erodent size. To complement the experimental analysis, an artificial neural network (ANN) model is developed to simulate the wear process and predict erosion rates across varying conditions. This approach minimizes the need for extensive experimental testing, providing a reliable and resource-efficient method for evaluating wear behavior. The composites exhibit considerable promise for industrial applications, including conveyor belt rollers, pulverized coal transport pipes in thermal power plants, pump and impeller components, and economical housing materials.

Keywords: Polymeric composites, Bio-fiber, SiC, Taguchi method, Erosion, ANN

1. Introduction

By incorporating hard filler particles into polymeric composites, synergistic effects have been achieved, leading to enhanced stiffness and reduced production costs [1]. The primary purpose of adding such fillers to polymers for industrial applications is to lower expenses while simultaneously improving rigidity [2]. A wide range of materials has been examined as potential fillers in these composites, as evidenced by existing studies [3]. Polymer composites filled with ceramics, such as Al2O3 and SiC, have garnered significant attention in recent years, with several studies emphasizing their efficacy as particle fillers [4].

Natural fiber-reinforced polymer composites, utilizing materials like sisal, coir, and jute, have been extensively employed in various structural applications. Recently, bio-fibers

derived from animal sources, such as whiskers and bird or chicken feathers, have gained increasing interest among researchers [5]. However, the potential use of fish scale fibers in composite fabrication remains underexplored. Pradhan et al. [6] were pioneers in reporting the development of epoxy composites reinforced with fish scales. More recently, composites integrating hard particle fillers with fish scale flakes have been introduced [7]. Despite these advancements, the application of artificial neural networks to predict the wear behavior of such composites has yet to be fully investigated. This study seeks to analyze the erosive wear behavior of innovative bio-fiber (fish scale)-reinforced polymer composites filled with micro-scale SiC particles. Additionally, it employs Artificial Neural Networks, inspired by biological neural systems, to predict their wear characteristics [8].

2. Experimental Procedure

2.1 Composite Fabrication

The epoxy resin (LY-556) curing at low-temperature and corresponding hardener (HY951) is mixed in a 10:1 weight proportion as per the manufacturer's recommendation. Three different composite formulations are prepared with varying SiC contents (0, 10, and 20 wt%). The fiber load is consistently maintained for all the samples at 10 wt%. The composite mixtures are then cast and subjected to a curing process under a constant load for 24 hours at room temperature to ensure proper hardening. Specimens of appropriate dimensions are subsequently made using a diamond cutter to prepare for the wear experiment.

2.2 Erosion Test Apparatus

The erosive tests are conducted using an apparatus designed to meet ASTM G 76 standards. Reproducible erosive conditions can be generated using this setup. Silica sand particles of varying sizes (300, 500, and 800 μm) are mixed with dry compressed air and is fed at a constant rate. The particles are directed toward the specimen, which is positioned at adjustable angles relative to the direction of the particle flow using a swivel and adjustable sample clip. Prior to and after each erosion trial, the samples are cleaned with acetone, dried, and weighed with a precision electronic balance, accurate to ±0.1 mg. The weight loss is recorded to calculate the erosion rate.

2.3 Experimental Design

Design of experiments (DOE) is employed as an analytical tool to model and assess the impact of control factors on performance outcomes. This approach helps in identifying non-significant variables early in the process. Five parameters are considered for this study: angle of impingement, erodent size, stand-off distance, impact velocity and filler content (SiC), each at three levels. These parameters are analyzed using the L27 (3^3) orthogonal array design. While a full factorial experiment with five different parameters at three levels would require 243 runs (3^5 = 243), the Design of Experiment by Taguchi reduces this to just 27 runs, offering significant efficiency in experimentation.

2.4 Neural Computation

The erosive wear process is recognized as a non-linear problem with respect to its different variables, including both material properties and operating conditions. To achieve the desired minimum wear rate, it is essential to optimize the combinations of operating variables. A effective methodology is required to study and analyse these interdependencies. In the present piece of work, Artificial Neural Networks (ANN) are utilized as a statistical tool to model and predict the relationship between input and output

parameters. ANN is employed to train a database, which allows for accurate predictions of erosion wear behavior under varying conditions.

3. Results and Discussion

3.1. Analysis Using Artificial Neural Network (ANN)

In this review and investigation, three key parameters— size of erodent, content of Silicon Carbide (SiC), and impingement/incidence angle—are considered as the input variables. Each of these parameters is represented by single neuron, leading to a total of three neurons in the input layer of the ANN structure. Various ANN architectures were tested, and the optimal configuration was selected based on the criterion of minimizing the error.

The variables/parameters for the chosen three-layer ANN structure are as: three nodes of input, one node output, and eight hidden nodes. The training process uses the following settings: error tolerance of 0.003, momentum of 0.002, noise factor of 0.001, learning rate of 0.002 and a maximum of 1,000,000 iterations. These parameters facilitate the generation of predicted outputs for the specific wear rate of the composite samples under varying test standards.

The back propagation-based neural network model was implemented using the NEURALNET software package, which serves as the predictive tool for determining the specific wear rate. The architecture of this three-layer neural network is depicted in Fig. 2.

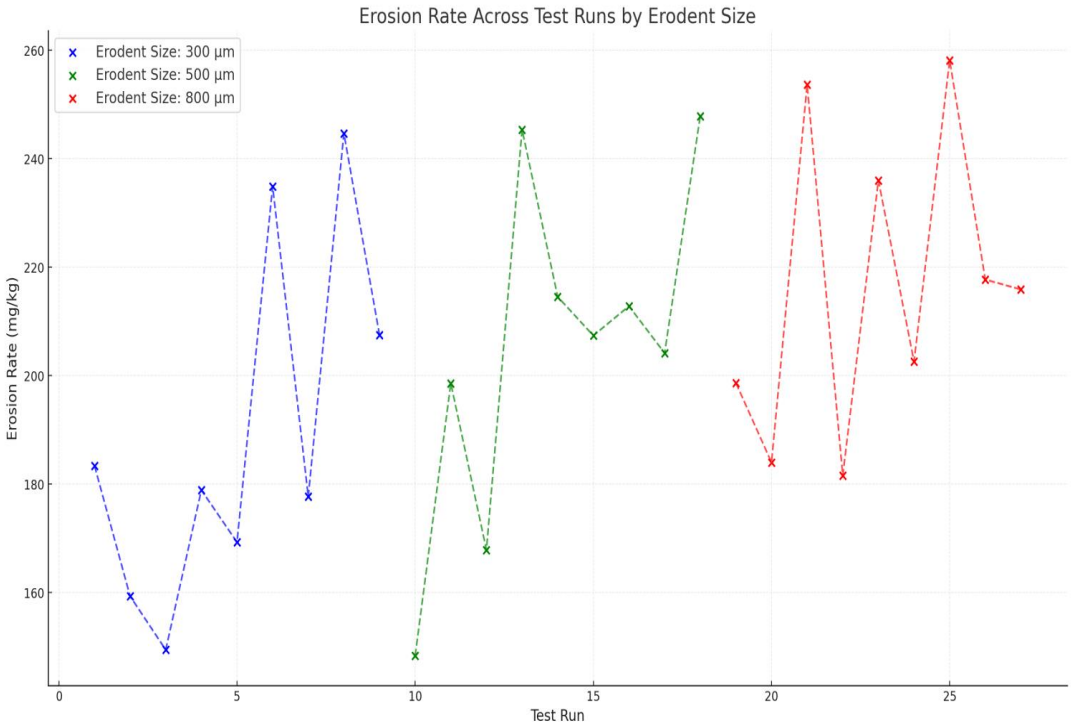

Figure 1. Erosion rates under various test conditions

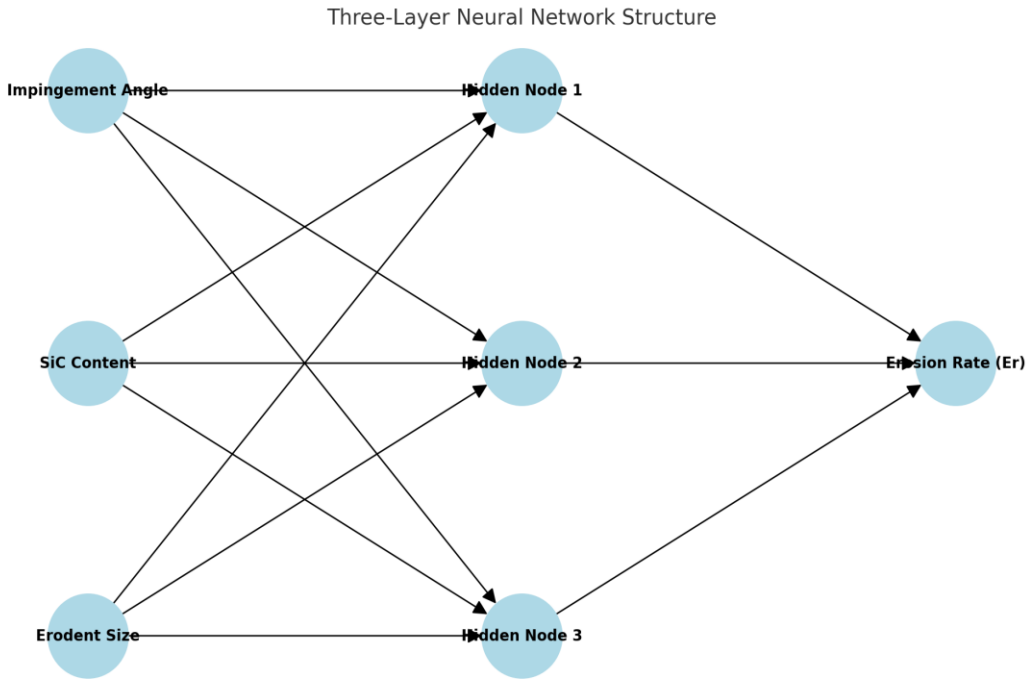

Figure 2. "Three-Layer Architecture of the Neural Network"

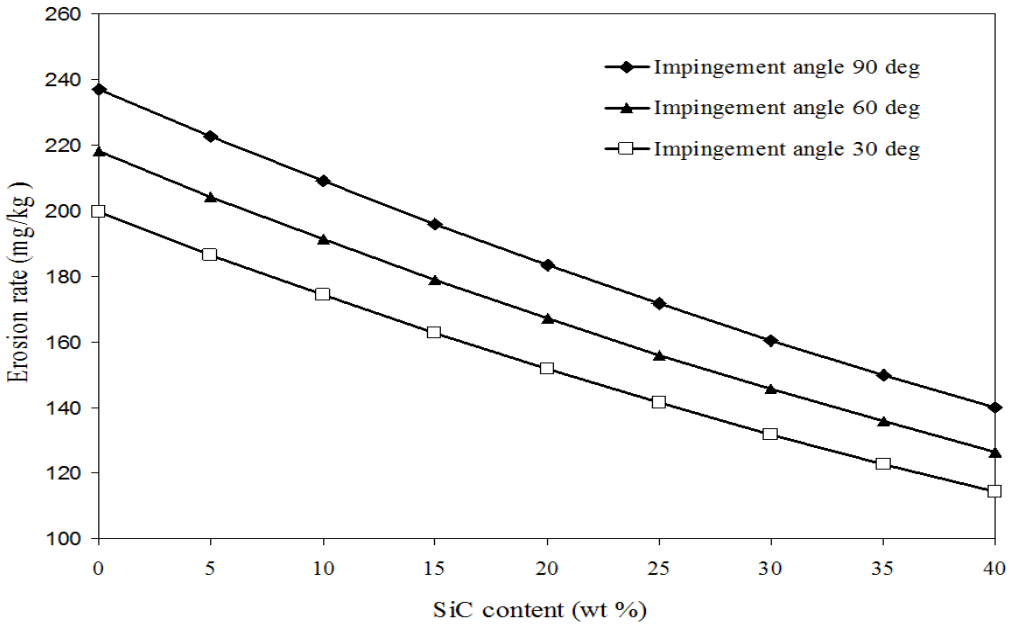

Figure 3. "Influence of Impingement Angles and SiC Content on Erosion Rate Variations"

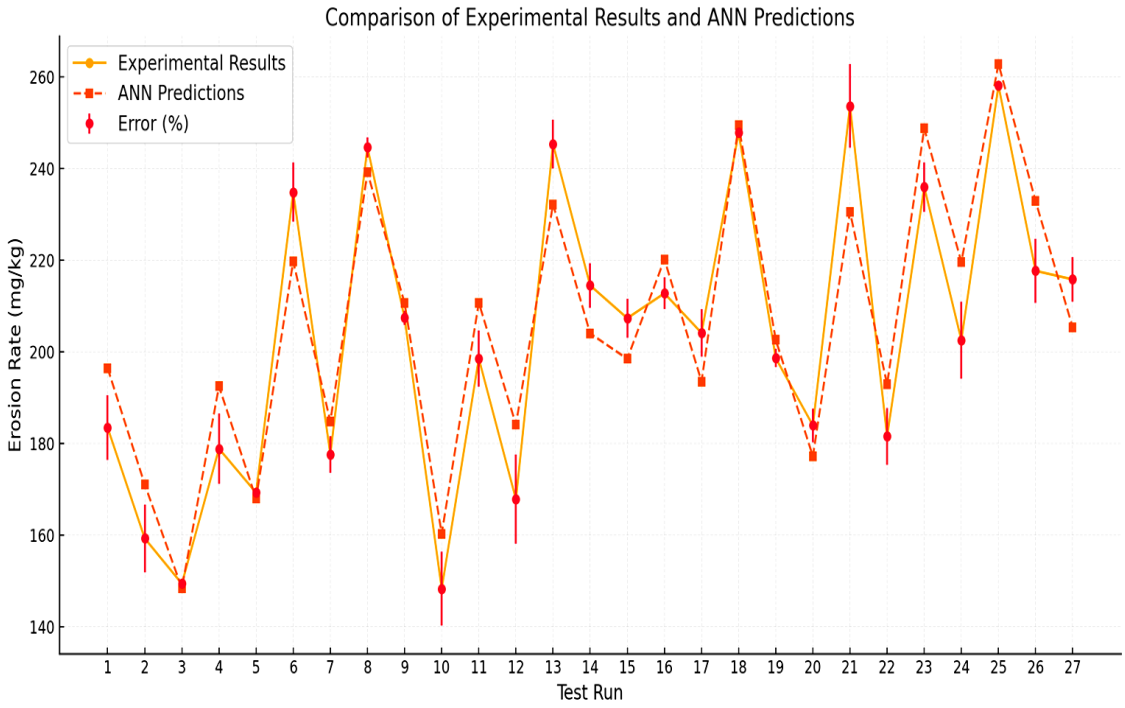

Figure 4. "Correlation Between ANN Predictions and Experimental Erosion Rates"

Figure 4 compares between the experimental results and the predictions made by the Artificial Neural Network (ANN). It can be observed that the errors between the experimental data and the ANN predictions are within the range of 0–8% across all test runs, which confirms the reliability of the neural computation. The erosion wear rates obtained by simulation, which highlight the result of varying SiC content, are shown in Fig. 4. Notably, there is decrease in erosion wear rate almost linearly with increasing SiC content in the composites, regardless of the impingement angle.

4. Conclusions

The findings of this study highlight the following key points regarding the solid particle erosion wear behavior of SiC-enhanced epoxy composites:

Design-of-Experiment Efficacy: The use of a structured design-of-experiment methodology effectively analyzed the wear characteristics of the composites, offering valuable insights into the influence of critical control factors.

Role of SiC as a Filler: Silicon carbide (SiC) was confirmed as an excellent filler material, significantly enhancing the composites' resistance to erosive wear by improving their durability under varying test conditions.

ANN-Based Modeling and Prediction: The application of artificial neural networks (ANN) in this study successfully simulated and predicted the wear behavior of the composites.

The ANN model demonstrated high accuracy in forecasting erosion rates based on filler content and test parameters, both within and beyond the experimental domain.

Impressive Predictive Capability: The well-trained neural network proved its reliability and efficiency as a tool for modeling wear performance, reducing the need for extensive physical experimentation.

This comprehensive approach, combining experimental methods and advanced predictive modeling, highlights the potential of SiC-enhanced composites in various applications where wear resistance is critical.

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Mutation Testing Via Path Coverage Test Data

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Abstract

Mutation Testing is a mistake located unit experiment at which point mistakes are discovered by executing sure test dossier devised by some white box experiment method. This paper presents a assorted design for path experiment in addition to metamorphosis experiment by generating the test dossier without thinking utilizing Genetic Algorithm. In the projected approach first path inclusion located test dossier is generated and further that dossier is exerted to cover all mutants present in the distinguishing program under test. The projected method can help the experiment adeptness by remove the redundant test dossier acquired from the course experiment in terms of better metamorphosis score and weakness discovery form is used to delete the duplicate dossier top unchanging mutants.

Keywords: Software Test case, Genetic Algorithm (GA), Path Coverage, Mutation Testing, Automatic Test Generation, Fault Detection, Mutation Score, Mutant Killing

1. Introduction

Ensuring the feature and stability of operating system relies thickly on productive experiment. Therefore, operating system experiment is a critical stage inside the Software Development Life Cycle (SDLC) [1]. Software experiment methods are widely classification into two main types: Black-box experiment and White-box experiment. In Black-box experiment, the focus act proving the productivity located only on the recommendation, outside some information of the within rule form. Conversely, White-box experiment includes testing the within philosophy and beginning rule of the operating system to guarantee decent use [1, 2].

The experiment process understands an organized succession of steps, as described in Fig. 1. During this process, different experiment levels are used to the Software under Test (SUT), in the way that whole experiment, unification experiment, and whole experiment. Among these, part experiment serves as the groundwork for added types of experiment methods [3, 4], guaranteeing that individual parts of the spreadsheet function right before unification into best methods.

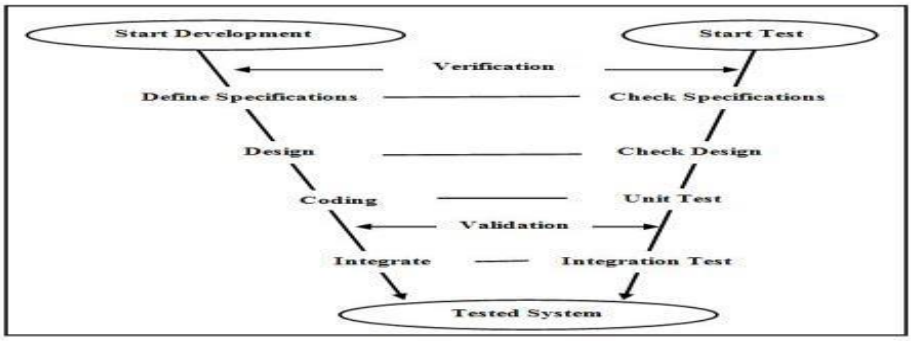

Fig. 1 V- Testing Model

Manual experiment is frequently obstructed by restraints in the way that slow killing speed, extreme costs and period finance, shortage of skillful resources, excessive test cases, and wasteful or erroneous test evaluations. These restraints maybe efficiently sent by mechanized experiment methods [4, 5]. Studies signify that almost 50% of spreadsheet happening money are assigned to experiment ventures. By executing electrical experiment, both happening costs and period maybe considerably decreased [6].

The experiment process commonly encounters growth challenges had connection with occasion restraints, cost adeptness, and the big book of test dossier necessary for killing. These challenges maybe agreed by leveraging Genetic Algorithms (GAs) to solve all-encompassing best answers [7, 8]. This paper presents a novel approach that uses Real-Coded Genetic Algorithms (RCGA) to produce way inclusion-located test dossier. The create test dossier is afterward used to Mutation Testing to recognize and remove mutants in the Software Under Test (SUT).

The residue concerning this paper is arranged in this manner:

- Section 2 expands on the Mutation Testing method.
- Section 3 argues the Genetic Algorithm controllers working in the projected arrangement.
- Section 4 determines a survey of accompanying bother Mutation Testing utilizing Genetic Algorithms.
- Section 5 outlines the projected methods for produce course inclusion-located test dossier and optimizing it for Mutation Testing.
- Section 6 presents the results of the projected approach through a record of what happened.
- Section 7 focus on future research guidance.

2. Mutation Testing

Unit experiment serves as the bedrock for all added experiment methods, and if performed insufficiently after experiment stages concede possibility demand supplementary opportunity and possessions. Therefore, part experiment is fault-finding for guaranteeing prime and trustworthy spreadsheet [9]. Mutation Testing is a weakness-located experiment method place deliberate pertaining to syntax wrongs are received into the Software Under Test (SUT) to determine the influence of test cases. The reduced adaptation of the SUT holding these mistakes is refer to as the mutated spreadsheet [6]. This method was originally grown by Offutt and Inch [10] and is devised to embellish the feature of test dossier by detecting and removing these by artificial means constituted sins, or mutants. The adeptness of the test dossier is calculated utilizing the Mutation Score that signifies in what way or manner efficiently the test cases recognize these mutants [11, 12, 13].

In the projected approach, test dossier produce for way inclusion is working for Mutation Testing. To advance this process, Genetic Algorithm (GA) is promoted to create a inclusive test series that achieves 100% way inclusion and efficiently kills all perceptible mutants.

3. Genetic Algorithm

A Genetic Algorithm (GA) is a effective developmental search method created to resolve complex addition questions. Inspired for one standard of normal progress and the idea of "continuation of the healthiest" [7], GAs iteratively develops resolutions by imitating organic processes. In the field of program design, GAs are widely working to address complicated and actual-planet challenges by certainly create excellent test dossier all the while the experiment aspect.GA usually engages four center drivers: Selection, Crossover, Mutation, and Elitism [8]. In this paper, the approach uses Real-Coded Representation [14], in addition to Average Crossover [15, 16]and Insertion Mutation [17] to produce new child chromosomes. These manipulators help polish the test dossier to obtain optimum resolutions capably.

4. Literature Survey

Last et al. [18] imported a fluffy-located enlargement of Genetic Algorithm (FAexGA) to mechanize test data creation and belittlement for detecting mistakes utilizing a mutated form of the original program. Their approach engages a Fuzzy Logic Controller (FLC) to regulate the crossover odds dynamically. Quyen et al. [19] Projected a GA-located method to underrate mutants in vital models, applying the Simulink finish for plan design. Their experiments showed a decline in moment of truth and cost of metamorphosis experiment outside waives facts. In their form, GA not only establishes a subgroup of mutants but too removes alive mutants inside bureaucracy. Khan et al. [11] grown an addition method for mechanical representative occurrence era through GA and metamorphosis reasoning. Their approach realized 100% course and frontier inclusion, accompanying test ability evaluated utilizing the metamorphosis score. The order corrects effectiveness by detecting the maximum number of mutants.

In [20]**,** the authors presented a GA-based method for optimizing test data efficiency, using a mutating function to measure test adequacy. Masud et al. [22**]** developed a GA-based model for fault detection and mutant killing. Their technique involves dividing the program into smaller units to test the mutants effectively**.** Rani and Suri [10] proposed a GA-based method for generating optimized test data by eliminating redundant data through delete mutant analysis, significantly reducing time and effort**.** Haga and Suehiro [13] introduced a GA-based technique using three specific mutation operators—COR, CSR, and BVI—to kill mutants. They employed a Detection Matrix to minimize the test cases before applying GA to generate new test data. Mishra et al. [23] presented a strategy for efficient test data generation in mutation testing, expanding on the work of Mattias Bybro [24] and Masud et al. [22] by using an elitist version of GA to identify faulty code units effectively.

5. Proposed Algorithm for Mutation Testing

Mutation experiment is a fundamental blame-located experiment method proposed at recognizing blames inside the Software Under Test (SUT). In this method, test cases are produce to discover distinguishing types of weaknesses inside the program. Initially, the SUT is proven accompanying a test series produce utilizing some silvery-box experiment

pattern, subsequently that metamorphosis experiment is acted by killing the alike test dossier [12, 25].In the projected order, the SUT has way experiment, place test cases are planned to reach100% report and arm inclusion by top all ways. Path experiment guarantees that all linearly liberated courses came from the program's Control Flow Graph (CFG) are performed [2, 9].

The aim of the projected invention search out design a representative test series that achieves 100% way inclusion and can afterward be secondhand for metamorphosis experiment. A Genetic Algorithm (GA) is working to create test dossier for complete course inclusion. The invention therefore optimizes the test series by removing excessive test dossier through the use of a Fault Detection Matrix (FDM) [13]. The overall flow of the treasure is pictorial in Fig. 4.

1.1 Fault Detection Matrix (FDM)

The Fault Detection Matrix (FDM) helps recognize that representative occurrence detects that mutation. An instance of an FDM is proved in Table 1, place three mutants (M1, M2, and M3) are discovered by test cases (T1, T2, T3, and T4).

Table 1. Test case and the mutants

	T1	**T2**	**T3**	**T4**
M1	1	0	0	1
M2	0	1	1	1
M3	0	1	0	1

Table 1 show that T1 detects only M1, while T2 detects M2 and M3, thus. This forge helps in recognizing excessive test cases and optimizing the test series respectively.

6. Experimental Setup

The projected invention has existed executed and proven on five widely acknowledged search-located operating system programs. The analyses of the Software Under Test (SUT), containing their Lines of Code(LOC) and the total number of ways thought-out, are summed up in Table 1. The appropriateness function in the projected approach measures the allotment of way inclusion worked out by a test series. This function evaluates the number of courses below each deoxyribonucleic acid. The beginning dossier for the Genetic Algorithm (GA) movements is defined in Table 2.

Table 2. Description of Programs Used for Experimentation

Subject Program	Program Name	Description	Lines of Code	Number of Paths
P1	Triangle Classifier Problem (TCP) [5, 8, 28, 34]	Classifies triangles as Equilateral, Isosceles, Scalene, or Not a Triangle	28	5
P2	Max_three [35]	Determines the maximum of three numbers	28	5
P3	Evaluate XY [35]	Computes the value of XY for given inputs X and Y	37	6
P4	Evaluate X/Y [35]	Computes the value of X/Y for given inputs X and Y	40	6
P5	GCD of Two Numbers (GCD) [4]	Calculates the greatest common divisor of two numbers	18	5

For metamorphosis experiment, mistakes are intentionally introduced into the law of the various SUTs, as particularized in Table 7. The appropriateness function, outlined ceremony of courses concealed per deoxyribonucleic acid. The results acquired from the GA movements are further judged utilizing metamorphosis experiment, place test dossier ability is calculated apiece Mutation Score, as particularized in Equation (3). The Fault Detection Matrix (FDM) helps decide the minimum number of test cases necessary for entire mutation inclusion.

Table 3. Parameters for GA Operations

S.N.	Parameter	Value
1	Population Size	10
2	Input Range	1 to 50
3	Encoding Type	Real Encoding
4	Crossover Type and Rate	Average Crossover (AX), 0.8
5	Mutation Type and Rate	Insertion Mutation, 0.02
6	Number of Generations	5

This arrangement guarantees that the GA limits are clear for produce optimum test dossier. The test series came from these movements is afterward judged for allure skill to

discover all introduced mistakes through metamorphosis experiment.

6.1 Result Analysis

The steps of the projected treasure and the results got through the Genetic Algorithm (GA)movements are outlined in Tables 3, 4, and 5. The test series produce to reach 100% course inclusion is proved in Table 6. The Fault Detection Matrix (FDM) arisen the developed test series is bestowed in Table 8, illustrating the mutation inclusion by each individual representative occurrence. The metamorphosis score, planned utilizing Equation (3), is given in Table 9, and the repetitious test cases have happened removed to yield the revamped test dossier, that is visualized in Fig. 7.

Table 4. Initial Population

Test Suite No.	Test Data	Target Path Fitness
1	(12,4), (8,27), (45,8), (9,44) 3,1,3,1	0.5
2	(14,9), (23,8), (33,45), (14,5) 2,2,2,3	0.5
3	(49,9), (7,33), (28,5), (39,8) 2,1,2,2	0.5
4	(7,12), (6,18), (16,4), (9,42) 1,4,3,1	0.75
5	(32,6), (44,16), (20,7), (17,12) 2,2,2,2	0.25

Table 5. Best Population

Test Suite No.	Fitness
1	0.5
4	0.75

Table 6. New Trait (After Crossover)

New Trait Test Data	Target Path Fitness
1 (9,8), (7,22), (30,6), (19,43) 2,1,3,1	0.75

Table 7. Path Coverage Test Data

Test Suite	Test Data	Target Path Fitness
(T1, T2, T3, T4)	(21,7), (14,9), (7,22), (6,18) 1,2,3,4	100%

Table 8: Mutant Details

Program Mutant No.	Operator Present	Replace with Operator
>	!=	M1
=	/=	M2
%	/	M3

!=	= =	M4
%	/	M5

Table 9: Fault Detection Matrix

Test Case / Mutant	T1	T2	T3	T4
M1	1	0	1	0
M2	0	0	1	1
M3	0	1	1	0
M4	1	1	1	1
M5	0	1	1	0

Table 10. Mutation Score

Test Case	Mutation Score
T1	0.4
T2	0.6
T3	1
T4	0.4

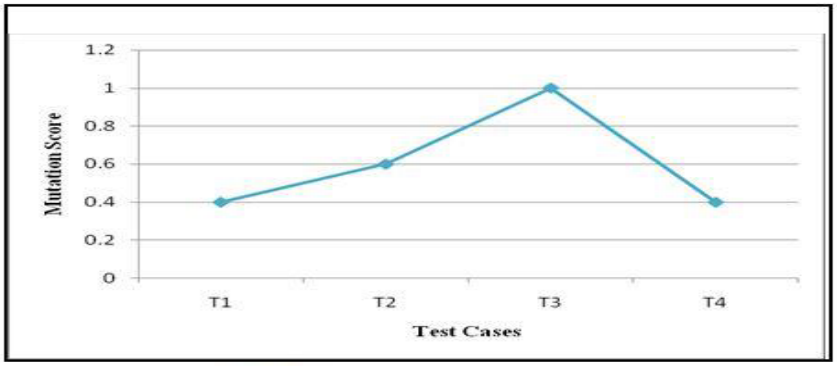

Fig. 7 Mutation Score of Test Cases

7. Conclusion and Future Work

Unit experiment is fault-finding for guaranteeing excellent and trustworthy operating system. Although Mutation experiment is famous for being computationally high-priced, it considerably corrects test dossier condition by obtaining larger Mutation Score, through growing the dependability of the program by detecting and removing alive mutants. The projected arrangement is worthy create test dossier for two together Path experiment and Mutation experiment. Through the use of Genetic Algorithm (GA), the arrangement capably produces test dossier that achieves 100% course inclusion, and the unchanging

test dossier is therefore secondhand for Mutation experiment to discover and remove mutants in the Software Under Test (SUT).

In future, we aim to investigate the growth of a assorted treasure that can in a more excellent manner produce test dossier expressly for Mutation experiment. Additionally, exertions ought toward construction an robotic finish that can produce mutants for a likely program under test, streamlining the process and making it more effective.

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Short Channel Effects: A major road roadblock for miniaturization of MOSFETs

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Abstract

Short channel effects (SCEs), a major problem for nano scale devices that cause a drop in device performance, are examined in this work. Moore's law anticipates higher packing density, mostly due to MOSFETs' ongoing downsizing. There are departures from the usual long-channel behavior for the reduced channel. A two-dimensional potential distribution and the existence of strong electric fields inside the channel region cause these variations, regarded as Short Channel Effects. Along with a number of important mitigation techniques, the paper discusses the phenomena of charge sharing, punch-through effect, and DIBL in ordinary MOSFETs.

Keywords: SOI technologies, high-K dielectrics, DIBL, charge sharing, sub-surface punch-through, and pocket implants.

1. Introduction

The closed proximity of source and drain due to the short channel length for a fixed channel doping concentration. Both E y and the drain bias have an impact on the potential distribution inside the channel [1-3]. This means that the gradual channel approximation is erroneous as the potential distribution assumes a two-dimensional character.

As technology becomes smaller (i.e., the channel length is reduced), the threshold voltage falls [4-5]. This is not desired since circuit designers want the threshold voltage to be constant irrespective of biasing conditions and transistor dimensions [6-9].

Underlying causes of short-channel effects (SECs):

- The channel's limitation on electron drift behavior,
- When the channel length is reduced, the threshold voltage changes.

Some noteworthy short-channel effects (SCEs) are as follows:

a. Charge Sharing: Because source and drain regions only make up a small portion of the channel region, their influence is negligible in long-channel devices [10-12]. On the other hand, the source and drain of short-channel devices cover a sizable area of the depletion region, which significantly increases the body impact. One term used to describe this

phenomenon is "charge sharing." The threshold voltage drops when charge sharing occurs because there is less space and charge beneath the gate.

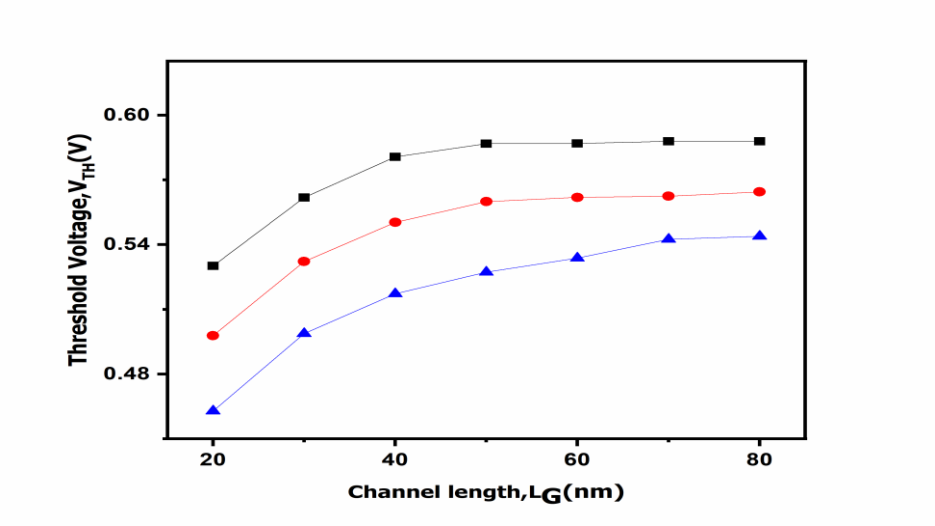

Figure 1. V_{TH} roll off

Figure 1: shows how this two-dimensional potential degrades V_{th} behavior and makes the threshold voltage rely on the biasing voltages and channel length.

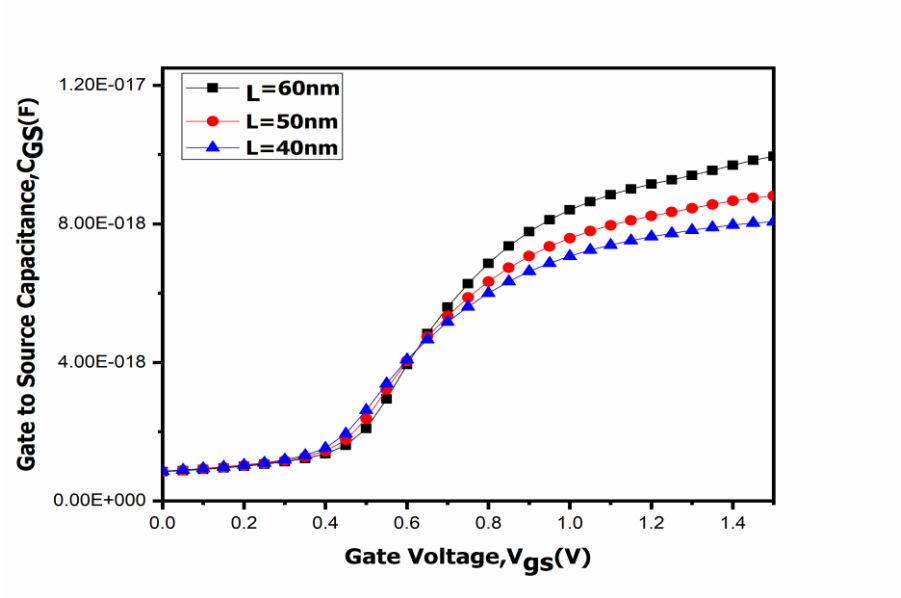

Fig 2. Comparison of gate to source charge in long channel and short channel MOSFETs

b. Sub-Surface Punch through

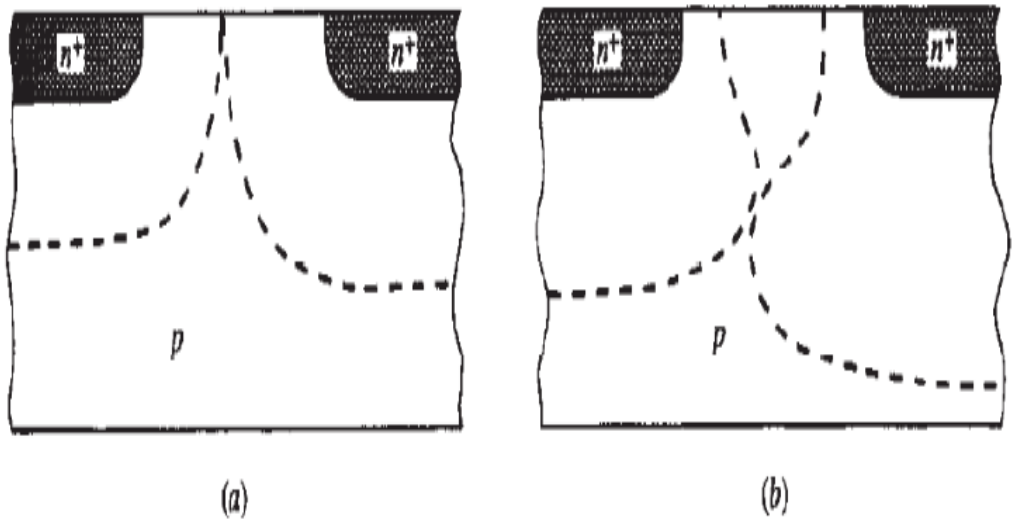

Fig 3. Sub-surface punch through

The space charge region surrounding the drain electrode can extend to the source electrode when the V_{ds} is high enough in relation to the source, allowing current to flow even when the gate voltage is zero. This process is called Subsurface Punch through. The punch-through voltage dramatically reduces as the channel length L (for short-channel devices) decreases. The drain and source junctions' depletion areas extend into the channel in these devices due to the closeness of the drain and source. Reducing the channel length while keeping the doping constant results in a decrease in the separation between the margins of the depletion regions [13]. Furthermore, a greater reverse bias across the junctions causes the depletion zones to get closer together. When the depletion regions combine due to a combination of increased reverse bias and decreased channel length, punch through takes place.

b. DIBL: Using the gate voltage, the potential barrier that separates the source and drain must be reduced. In short-channel devices, the drain voltage has a major impact on lowering this barrier and further influences it. The source and drain become electrostaticcally linked as they approach one another, as a result the drain bias affect the barrier at the source junction. As a result, the subthreshold current rises. By expanding with increasing bias, the drain depletion zone can interact with the source-to-channel junction and lower the potential barrier. This phenomenon is Drain-Induced Barrier Lowering (DIBL) [14]. Lowering the barrier at the source makes it simple to introduce electrons into the channel, making the gate voltage useless for regulating the drain current. Since the source and drain of long-channel devices are far enough apart, the potential distribution in the majority of the device is not affected by the depletion zones of either. 0Channel length and drain bias therefore have little effect on the threshold voltage in such devices. However, shorter channel lengths and higher drain voltages cause DIBL to become more noticeable.

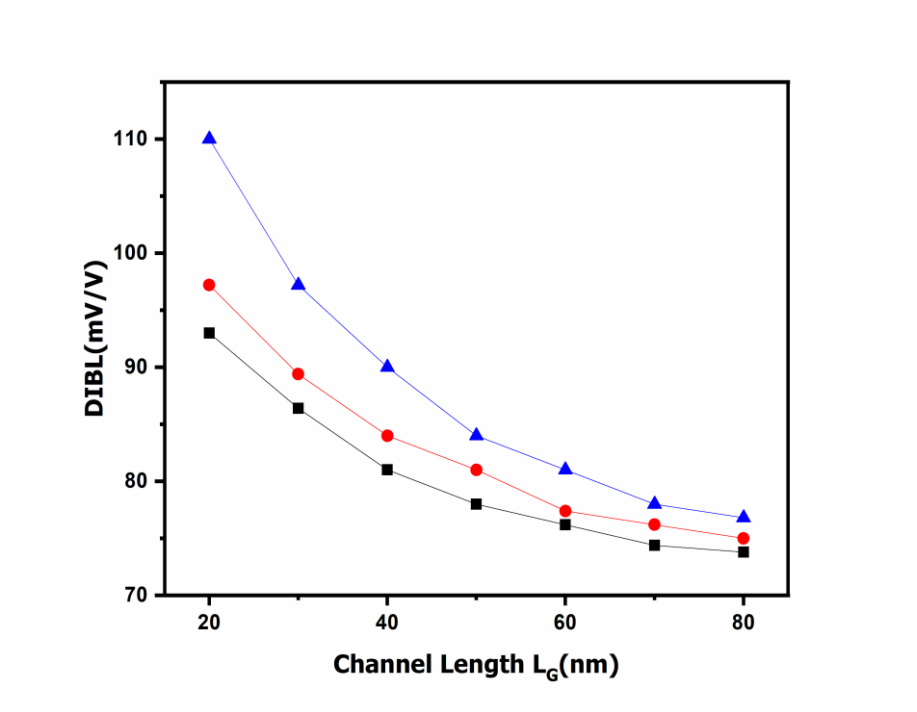

Fig 4. Drain-Induced Barrier Lowering (DIBL)

2. Remedies:

High-permittivity Dielectric stacking: "High-k" describes a substance that has a high dielectric constant, indicating that it can store charge. The ability of various materials to store charge varies. The transistor can flip between "ON" and "OFF" states more efficiently with a higher "K" value because it increases its capacitance, which permits high current in the "ON" state while keeping very low current in the "OFF" state [13]. 0High-k gate dielectrics operate cooler because they are much thicker and lower gate leakage by more than 100 times. Without increasing leakage effects, gate capacitance can be increased by substituting a high-k material for the silicon dioxide gate dielectric.

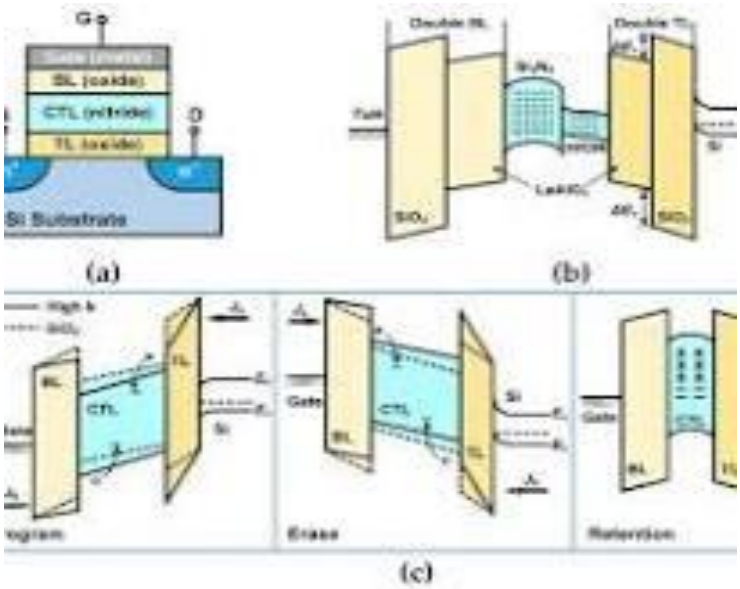

Fig 5. High-permittivity dielectrics

2. Implantation of packets: An adjustable implant is utilized in sub micrometer MOSFETs to attain more surface doping in comparison to the bulk. As a result, the depletion region below the surface expands more because of the decreased doping concentration there.

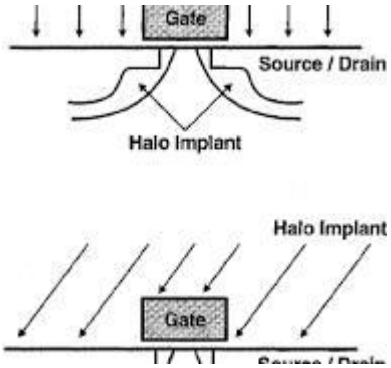

Fig 6. Pocket Implantation: Halo Doping

As an additional technique to control the threshold voltage's reliance on channel length, halo doping—which is characterized by a non-uniform channel profile along the lateral direction—was used for technology nodes smaller than 0.25 µm. Regions with increased p-type doping are added close to the ends of the channel in n-channel MOSFETs. Near the channel's future ends, point defects are created beneath the gate's margins during sidewall oxidation. Doping impurities from the substrate are drawn to these flaws. In order to reduce the depletion regions in the drain-substrate and source-substrate areas, a more strongly doped p-type substrate is used close to the channel margins. This reduces the charge-sharing effects from the source and drain field.[13]. 0Such severely doped patches take up a larger share of the entire channel as the channel length shrinks. They aid in mitigating the degradation of threshold voltage brought on by channel length reduction by lowering charge-sharing effects. 0The threshold voltage consequently shows more stable behavior and is less reliant on channel length. DIBL is also lessened by the reduction of barrier lowering in the channel caused by the shortening of the source and drain junction depletion areas.

3. Shallow structure of source and drain

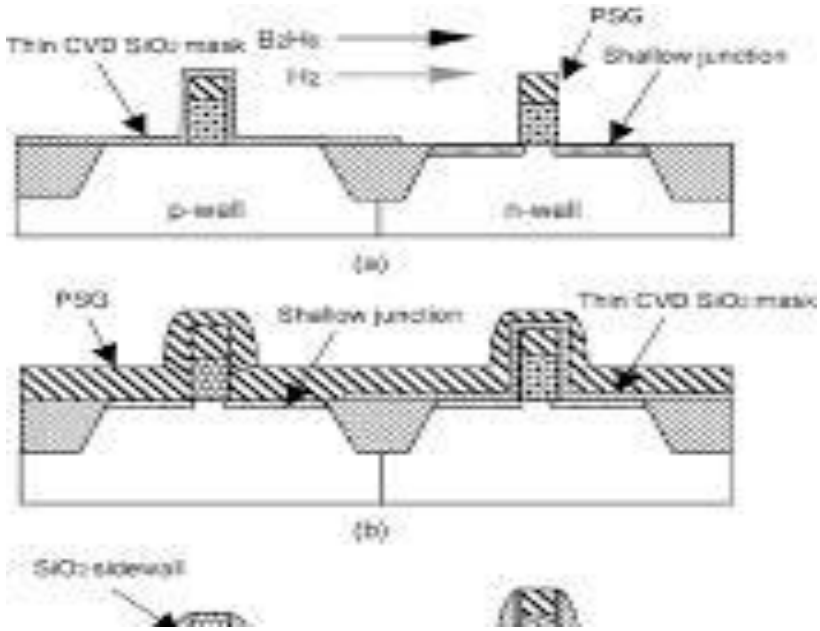

Fig 7. Shallow structure of source and drain regions

- Low junction resistance (r j) shallow source/drain (S/D) areas are preferred in order to reduce short-channel effects (SCE). Nevertheless, in certain areas, parasite resistance rises when r j is decreased.
- Junction resistance (r j) can be efficiently reduced by shallow source/drain (S/D) extensions without appreciably raising S/D sheet resistance. The effect of DIBL on subthreshold leakage current is lessened by shallow S/D junction depths and higher surface and channel doping.

2. SOI (Silicon on Insulator)
   In semiconductor production, especially in microelectronics, SOI technology [3] entails the use of SOI layered substrate as opposed to a traditional silicon substrate. This method improves performance by lowering the capacitance of parasitic devices [14].

- It is thought that thin-film SOI transistors that have been fully depleted have less short-channel effects (SCEs).
- Our goal with modern technology is to make everything fit into smaller spaces. Doping densities must be raised when device dimensions decrease in order to guarantee correct operation. It gets difficult to manage this, though, when device sizes go closer to 50 nm and smaller. 0They demand lower doping densities for thin-film devices such as full depletion SOI. Because of this, SOI might be a better option for next procedures than bulk CMOS [15].
- Speed is mostly determined by the parasitic drain and source junction capacitances' relative magnitudes in relation to the gate capacitance in bulk devices. As device dimensions decrease and doping levels increase, this magnitude grows. By comparison, the parasitic capacitances of SOI technologies are substantially lower than those of bulk technologies.
- Because of their smaller active silicon volume, SOI devices are less vulnerable to high-energy particles than bulk technology. SOI devices are therefore ideal for radiation-hardened applications because of this feature [16-19].
- Integrated circuits that run at low supply voltages with low power consumption are in high demand due to the increasing popularity of battery-powered gadgets. With SOI's superior suitability for low-voltage applications, this trend also supports SOI's future acceptance over bulk technology.
- The speed of SOI devices is increased by their higher current drive capabilities compared to bulk devices. Speed and power can be traded off in this way, allowing for the creation of devices that are as fast as bulk devices but use less power.
- Thin-body SOI with raised source and drain, buried insulator optimization, graded-channel SOI, halo-doped SOI, ground-plane SOI, and multi-gate SOI are some of the techniques described in the literature to increase the resistance of SOI MOSFETs to short-channel effects.

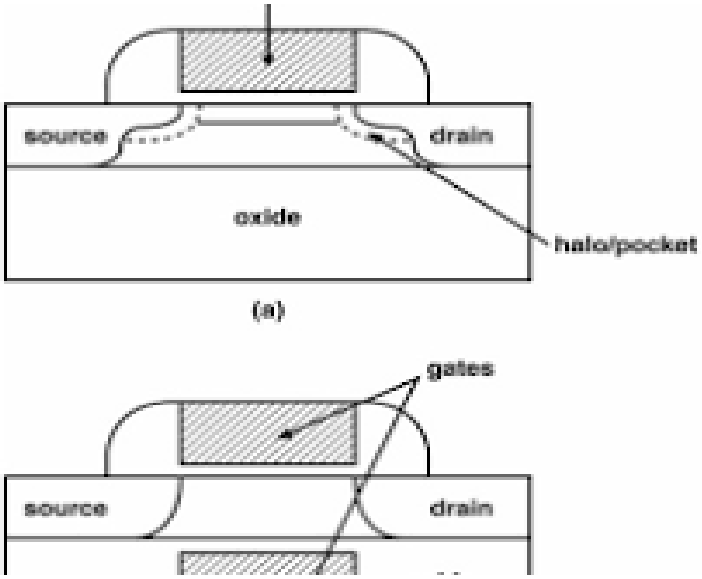

Fig 8: Silicon on Insulator Devices

3. Conclusion

The gate loses some control over the channel charge when it couples directly with the source or drain rather than the channel, which results in short-channel effects (SCEs). Better SCE reduction and increased device reliability have been demonstrated by methods such channel engineering, pocket implants, shallow source and drain junctions, well-designed high-k material stacks, and the SOI technique.

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