

## Research Article

# Development of Novel Nano-Silver-Based Antenna for Green Agriculture

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Received 1 July 2021; Accepted 12 August 2021; Published 28 September 2021

Academic Editor: Samson Jerold Samuel Chelladurai

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The designed antenna is a monopole Z-shaped antenna operating in an unlicensed band of 2.4 GHz fabricated using low cost inkjet printing technology. The proposed inkjet printing technology is eco-friendly since the material used here is an ordinary “paper” that is suitable for the green technology. The conducting patch of silver nanoparticle (AgNP) ink has very high conductivity 35,700,000 S/m and instant curing property which helps in fabrication process without UV curing or oven heating. The printer used also is the cheap home printer HP DJ 2130 rather than the expensive Brother and Epson printers used in previous works. The printed antenna will be helpful in conditions to ascertain its performance in green agriculture in the form of RF-ID sensors, soil pH value sensor, and moisture sensor. The proposed antenna attains the gain of 2.5 dBi at the ISM band of 2.4 GHz with optimal VSWR value between 1 and 2 over the desired frequency band. The directivity and radiation efficiency of the proposed antenna are 2 dBi and 80%, respectively. The overall cost of the proposed antenna is much lesser in the order of 10 times than the recent low cost design.

## 1. Introduction

Green agriculture is the revolution of Indian agriculture that addresses the problems such as land pollution, biodiversity, and climate change. The land preservation can be done by controlling the addition of pollutants into the soil. Fertilizers, nonbiodegradable waste, and e-waste are the causes of land pollution. The quality and quantity of such pollutants need to be measured for the upgradation of soil property. In our country, for strengthening the high biodiversity areas, the transformation of agricultural systems is highly essential. To catalyze transformation in agricultural sector, more concentration towards the sustainable

landscape management is needed. Land is a vital resource to humankind, like air and water. Land degradation is the deterioration or loss of the productive capacity of the soils for the present and future. This is a global challenge that affects everyone through food insecurity, higher food prices, climate change, environmental hazards, and the loss of biodiversity and ecosystem services. Land pollution is happening at an alarming pace, contributing to a dramatic decline in the productivity of croplands and rangelands worldwide [1–3]. Hence, rapid remedial action is essential for developing green agriculture system in our country. Hence, an array of antennas that acts as a sensor for measuring various on-field parameters of the agricultural

# NSCT and focus measure optimization based multi-focus image fusion

**Article type:** Research Article

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**Abstract:** Getting a complete description of scene with all the relevant objects in focus is a hot research area in surveillance, medicine and machine vision applications. In this work, transform based fusion method called as NSCT-FMO, is introduced to integrate the image pairs having different focus features. The NSCT-FMO approach basically contains four steps. Initially, the NSCT is applied on the input images to acquire the approximation and detailed structural information. Then, the approximation sub band coefficients are merged by employing the novel Focus Measure Optimization (FMO) approach. Next, the detailed sub-images are combined using Phase Congruency (PC). Finally, an inverse NSCT operation is conducted on synthesized sub images to obtain the initial synthesized image. To optimize the initial fused image, an initial decision map is first constructed and morphological post-processing technique is applied to get the final map. With the help of resultant map, the final synthesized output is produced by the selection of focused pixels from input images. Simulation analysis show that the NSCT-FMO approach achieves fair results as compared to traditional MST based methods both in qualitative and quantitative assessments.

**Keywords:** Image fusion, multi-focus, NSCT, focus measure, decision map

**DOI:** 10.3233/JIFS-202803

**Journal:** [Journal of Intelligent & Fuzzy Systems](https://content.iospress.com:443/journals/journal-of-intelligent-and-fuzzy-systems) (https://content.iospress.com:443/journals/journal-of-intelligent-and-fuzzy-systems), vol. 41, no. 1, pp. 903-915, 2021

**Published:** 11 August 2021

**Price:** EUR 27.50

## Roadmap to Biomedical Image Segmentation and Processing – Background and Approaches

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### Abstract-

The exponential growth in digital imaging and computer vision in ophthalmology has enhanced the ability to implement progress in the processing of images. In the production of medical diagnostic systems, image processing tools are used in regular clinical procedures. Retinal images contain valuable information regarding the status of the visual system sensory component. The retinal image can lead to a decrease in blindness, as an object, in retinal diseases such as glaucoma, diabetic retinopathy, age-related macular degeneration, Stargardt disease, and premature retinopathy. An automated system can be used to obtain standardized, low-cost, huge-scale screening that can take human mistakes, provide remote areas with services, as well as safe bias and exhaustion of availability. Retinal diseases are being therapized but an extremely complex, cost-effective solution to identify those at risk at the early stages of the disease can be delivered quickly to larger populations. The realistic account of all challenges and opportunities of medical imaging from engineering perspectives requires a complete study of available methods. Objective: In this chapter, huge potential efforts are made to study the complete background of medical imaging segmentation with the detail of how machine learning contributed to biomedical science. Methods: Machine learning models. Findings Roadmap of machine learning to image segmentation. Novelty Methods are described by appropriate methods of processing.

**Keywords:** *Biomedical, Machine Learning, Medical Imaging, Retinal Image, Segmentation.*

### 1. Introduction

Medical imaging has become the social health care group's most important tool; this is attributable to the visual paperwork and record storage of patients and their ability to produce

# Classifying Indian Medicinal Leaf Species Using LCFN-BRNN Model

**Kiruba Raji I<sup>\*</sup>, Thyagarajan K.K<sup>2</sup>, Vignesh T<sup>3</sup> and Kalaiarasi G<sup>4</sup>**

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*Received April 4, 2021; revised June 14, 2021; accepted August 1, 2021;  
published October 31, 2021*

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## Abstract

Indian herbal plants are used in agriculture and in the food, cosmetics, and pharmaceutical industries. Laboratory-based tests are routinely used to identify and classify similar herb species by analyzing their internal cell structures. In this paper, we have applied computer vision techniques to do the same. The original leaf image was preprocessed using the Chan-Vese active contour segmentation algorithm to efface the background from the image by setting the contraction bias as  $(v) - 1$  and smoothing factor ( $\mu$ ) as 0.5, and bringing the initial contour close to the image boundary. Thereafter the segmented grayscale image was fed to a leaky capacitance fired neuron model (LCFN), which differentiates between similar herbs by combining different groups of pixels in the leaf image. The LCFN's decay constant ( $f$ ), decay constant ( $g$ ) and threshold ( $h$ ) parameters were empirically assigned as 0.7, 0.6 and  $h=18$  to generate the 1D feature vector. The LCFN time sequence identified the internal leaf structure at different iterations. Our proposed framework was tested against newly collected herbal species of natural images, geometrically variant images in terms of size, orientation and position. The 1D sequence and shape features of aloe, betel, Indian borage, bittergourd, grape, insulin herb, guava, mango, *nilavembu*, *nithiyakalyani*, sweet basil and pomegranate were fed into the 5-fold Bayesian regularization neural network (BRNN), K-nearest neighbors (KNN), support vector machine (SVM), and ensemble classifier to obtain the highest classification accuracy of 91.19%.

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**Keywords:** Chan-Vese segmentation, Leaky Capacitance and Fired Neuron (LCFN), time sequence, Bayesian Regularization Neural Network (BRNN), computer vision

## ARTICLE

# A Comprehensive Analysis of Short Channel Effects on Carbon Nano Tube Field Effect Transistors

P. Arul\* and K. Helen Prabha

As the direction of World health organization (WHO) report the diseases like male infertility, brain tumor, hearing impairment, fetus issues, effect on eyes and other various parts of the human body caused by harmful radiations released by portable electronic devices. To reduce radiation and size, a deep scaling has been applied on MOSFETs. Due to this aggressive scaling MOSFET devices are affected by Short Channel Effects (SCE) in Nanometer regime ( $< 10$  nm). The Short Channel Effects Such as Subthreshold Swing (SS), Drain Induced barrier Lowering (DIBL) and threshold voltage roll-off ( $V_T$ ), plays a key role in determining the performance of CMOS devices. At Nano-meter scale Carbon Nano Tube FETs (CNTFETs) devices might be furnished with good control on leakage current and power consumption. The comparative analysis of Subthreshold Swing (SS), Drain Induced Barrier Lowering (DIBL) and  $I_{on}/I_{off}$  ratio on Conventional Single Gate MOSFET (C-MOSFET), Double Gate MOSFET (DG-MOSFET) and CNTFET devices are presented in this paper. The results of comparative analysis show that CNTFET exhibits 133% times more  $I_{on}/I_{off}$  ratio than MOSFET and very less change in Subthreshold swing and DIBL.

**Keywords:** C-MOSFET, DG-MOSFET, CNTFET, Short Channel Effects, Subthreshold Swing, DIBL,  $I_{on}/I_{off}$  Ratio.

## 1. INTRODUCTION

Complementary MOSFET or Conventional MOSFET (C-MOSFET) devices are predominantly used in fabrication integrated circuits since 1968. Gordon Moore, Co-founder of Intel Corporation discovered and that the density of transistors had doubled for every sq. Inch on integrated circuits per year and cost is halved [1]. Semiconductor industries were contented with Moore's Law for the last four decades and manufactured an IC with high density. In recent years Moore's Law is questionable in the giant invention of Integrated Circuit fabrication. As the regulation of ITRS 2017, International Technology Roadmap for Semiconductor report [2]. Semiconductor technology has extremely changed with size, speed, and the overall dimensions of the device. The scaling of the MOSFET dimension is the predominant factor for reducing the size and supply voltage of ICs. The channel length was scaled

down at 65 nm and 45 nm as well the gate oxide thickness result of the power limitations from the increase in gate leakage current [3]. To overcome this drawback in the 32 nm technology a high-k materials like  $HfO_2$ ,  $TiO_2$  and  $Al_2O_3$  have been introduced. This enabled good gate leakage reduction while scaling the oxide thickness by below 3 nm. In these nodes, DG-MOSFET is widely expected to good results than a Single gate MOSFET.

For furthermore scaling technology anticipated to reach below 10 nm, the Current CMOS devices are not fit into the IC fabrication process even if use high-k dielectric materials. Low gate oxide thickness less than 5 nm causes more Subthreshold current and it leads to high power dissipation and the reliability of the device will be reduced [4]. Yet MOSFET scaling will reach 10 nm might not be feasible, because silicon technology will soon reach its limit. So the semiconductor industries and researchers have been working on finding alternate materials for replacing CMOS for future shrinking. Carbon Nanotubes, Graphene FET's and Tunnel FET's are attractive devices in the Nano-scale regime.

Carbon Nano Tubes (CNTs) are likely looking for material for future generation electronic devices. A lot of research progress has been made in the last few years

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Received: 18 November 2021

Revised/Accepted: 10 January 2022

# Image Manipulation Detection Through Laterally Linked Pixels and Kernel Algorithms

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Received: 17 May 2021; Accepted: 01 July 2021

**Abstract:** In this paper, copy-move forgery in image is detected for single image with multiple manipulations such as blurring, noise addition, gray scale conversion, brightness modifications, rotation, Hu adjustment, color adjustment, contrast changes and JPEG Compression. However, traditional algorithms detect only copy-move attacks in image and never for different manipulation in single image. The proposed LLP (Laterally linked pixel) algorithm has two dimensional arrays and single layer is obtained through unit linking pulsed neural network for detection of copied region and kernel tricks is applied for detection of multiple manipulations in single forged image. LLP algorithm consists of two channels such as feeding component (F-Channel) and linking component (L channel) for linking pixels. LLP algorithm linking pixels detects image with multiple manipulation and copy-move forgery due to one-to-one correspondence between pixel and neuron, where each pixel's intensity is taken as input for F channel of neuron and connected for forgery identification. Furthermore, neuron is connected with neighboring field of neuron by L channel for detecting forged images with multiple manipulations in the image along with copy-move, through kernel trick classifier (KTC). From experimental results, proposed LLP algorithm performs better than traditional algorithms for multiple manipulated copy and paste images. The accuracy obtained through LLP algorithm is about 90% and further forgery detection is improved based on optimized kernel selections in classification algorithm.

**Keywords:** Machine learning; copy move forgery; support vectors; kernel; feature extraction

## 1 Introduction

Recently, free image editing tools available in internet leads to duplication of image and detecting duplication in image is a major problem for many researchers. In this internet world, day-by-day digital photo plays a vital role in various e-commerce applications such as sales and marketing. Furthermore, sharing of digital image in social media is increasing exponentially. However, identifying original image needs efficient software tools based on type of duplication of image such as copy-move, splicing, digital watermarking, digital signature, and image compression and re sampling duplicated images. Among the above duplication of image, copy-move duplication is more in social media, due to availability of many



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# Forecasting Bitcoin price using time opinion mining and bi-directional GRU

[Cite](#)

**Article type:** Research Article

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**Abstract:** Bitcoin is an innovative decentralized digital currency without intermediaries. Bitcoin price prediction is a demanding need in the present situation. This paper makes an investigation on the Bitcoin price forecast with a Bi-directional Gated Recurrent Unit (GRU) time series method, combined with opinion mining based on Twitter and Reddit feeds. An hourly basis sentimental analysis through the implementation of Natural Language Processing presents a positive impact of sentimental analysis on the Bitcoin price prediction. For prediction, RNN, long-short memory, GRU has been utilized. Unidirectional and Bi-directional versions of all three networks with and without sentimental analysis were implemented for comparison. Of all the techniques implemented Bi-directional GRU along with sentimental analysis gives a minimum RMSE and Minimum absolute percentage error of 1108.33 and 7.384%. Thus, the framework including Bi-Directional GRU along with Sentimental Analysis provides better results than the State-of-art methods.

**Keywords:** Bitcoin, neural network, mining, GRU, RMSE, MAPE

**DOI:** 10.3233/JIFS-211217

**Journal:** [Journal of Intelligent & Fuzzy Systems](#), vol. 42, no. 3, pp. 1825-1833, 2022

**Published:** 02 February 2022

**Price:** EUR 27.50

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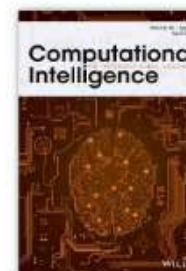
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## A composite framework of deep multiple view human joints feature extraction and selection strategy with hybrid adaptive sunflower optimization-whale optimization algorithm for human action recognition in video sequences

Rajitha Jasmine Rajappan ✉️, Thyagarajan Kondampatti Kandaswamy

First published: 18 January 2022 | <https://doi.org/10.1111/coin.12499>



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RESEARCH ARTICLE

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M Ayesha Nasreen Selvi Ravindran

First published: 18 April 2022 | <https://doi.org/10.1002/dac.5163>

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## Summary

Human-computer interaction plays a vital role in wireless body area networks, internet of things, and big data. Wearables are low-power devices with minimal battery capacity. In general, wearables suffer from energy losses due to changes in the user's body posture, diffraction, reflection, and shadowing of the human body. As a result, many



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## Multifunctional Agricultural Robot Operated Through Mobile Phone

Gladys Saro Sujithraa<sup>1</sup>, Karthigaiveni S<sup>1</sup>, Janani S<sup>1</sup> and Hymlin rose S G<sup>2</sup>

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[ECS Transactions, Volume 107, Number 1](#)

**Citation** Gladys Saro Sujithraa *et al* 2022 *ECS Trans.* **107** 5411

### + Article information

### Abstract

This paper proposes an AGRIBOT (agricultural robot) designed for agricultural purpose that aids the people to endure so that it achieves to do multi functions such as seedling, turn up the area of land, to put a mass of small drops of liquid on crops, lawn mowing, and to identify the hindrance. This AGRIBOT practices which is back powered by the sun energy. It also consists of a detector which detects the obstacles combining the bluetooth module that is directed by the instructions given to the AGRIBOT. This low cost AGRIBOT is easy to function without requiring personal assistance. It aids the farmers for ease of work to lessen the individual effort, time consumption, and energy. Despite all the obstacles, even day or night agriculture can be performed. This AGRIBOT when compared with all other robots is especially useful because it performs multiple functions that serve as an advanced technique for smart farming.

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## Use of Alexnet Architecture in the Detection of Bone Marrow White Blood Cancer Cells

Gladys Saro Sujithraa<sup>1</sup>, Karthigaiveni S<sup>1</sup>, Janani S<sup>2</sup> and Hymlin Rose S G<sup>3</sup>

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[ECS Transactions, Volume 107, Number 1](#)

**Citation** Gladys Saro Sujithraa *et al* 2022 *ECS Trans.* **107** 5567

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### Abstract

The cancer-affected area in white blood cell pictures is studied in this paper. AlexNet architecture is used to classify different types of white blood cells. This model, which was trained on cell pictures, first preprocesses the photos before extracting the best feature. The feature is extracted using the convolutional layer, Relu layer, and max pooling layer. For categorization of Eosinophils, Lymphocytes, Monocytes, and Neutrophils, the extracted features are input into a softmax and a completely linked layer. The various phases of image processing are used to improve the quality and accuracy of blood cancer detection. The accuracy of the blood sample image is determined by the affected area.

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Classification of Acute Myelogenous Leukemia (AML M2 and AML M3) using Momentum Back

## IoMT aware data collective quadratic ensembled cat boost module classification algorithm for non-invasive blood glucose monitoring in VLSI design

Cite

**Article type:** Research Article

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**Abstract:** Internet of Medical Things (IoMT) is the combination of medical devices and utilization by networking technologies. But, the response time and cost were not reduced. In order to address these issues, IoMT Aware Data Collective Quadratic Ensembled Cat Boost Module Classification (IoMT-DCQECBMC) Method is introduced. Initially, IoMT Aware Data Collection is used for gathering data from medical devices. After the data collection process, Quadratic Ensembled Cat Boost Module Classification (QECBM) is carried out in IoMT-DCQECBMC Method to design an efficient VLSI architecture with minimal cost and area. The quadratic classifier is considered the weak learner that categorizes the module for efficient VLSI design. Finally, the weak learners are joined to form the strong classifier to perform non-invasive blood glucose monitoring efficiently. Experimental evaluation is carried out on the factors such as computation cost, area, and accuracy with respect to a number of modules in VLSI circuits. The accuracy of the IoMT-DCQECBMC method is increased by 4% than conventional methods. In addition, the area consumption and computation cost of the proposed IoMT-DCQECBMC method are reduced by 13% to 30% other than existing methods.

**Keywords:** Very-large-scale integration, integrated circuit, healthcare information, diabetes mellitus, non-invasive blood glucose monitoring, weak learner, classification

**DOI:** 10.3233/JIFS-220315

**Journal:** Journal of Intelligent & Fuzzy Systems, vol. Pre-press, no. Pre-press, pp. 1-11, 2022

**Published:** 30 April 2022

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## **Comparative analysis of internet of things (IoT) in supporting the health care professionals towards smart health research using correlation analysis**

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### **ABSTRACT**

*The topic is focused on the Internet of Things (IoT) technology which has a vital impact on the health care sector currently. The professors, experts are mostly utilized the technology in the research. It helps to get authentic result in the research so that remote area can use the technology also. It has high benefits in economically that provides proper services within low price. It is essential nowadays to improve the medical sector in treatment as well as medicines. The layer of technology helps to do proper research as well as avail proper services. The technologies of the smart wearables that are used for the purpose of providing smart healthcare services are being oriented with the IoT to enhance them in various ways. This is also making them sustain more in the long run. Findings suggested that IoT in wheelchair management, healthcare solution using mobile and other factors have positively impacted the better healthcare services.*

**Keywords:** Internet of Things (IoT), layer of IoT, correlation analysis, healthcare, r-square

Received 11.02.2022

Revised 21.03.2022

Accepted 05.04.2022

### **INTRODUCTION**

Most of the health care sector can utilize advanced levels in the treatment process to decrease the extended access and prices along with providing enough facilities in treatment procedures. Standing on the 21st century the Internet of Thing (IoT) has a high level of utilization in different sectors, especially in the health care sector. It is an external support that aids the health care professionals to do a proper analysis or research on health care services. IoT system has a major role in the respective field regarding specification such as low-cost accessibility, minimum power sensibility in technology, machine learning analytics, efficient connectivity, and availability of cloud computing [1]. Depending on the accessibility the health care professionals choose the IoT system to use the researching purposes. There has no doubt about the application or utilization of IoT systems in the health care sector where it uses smartly. Moreover, the recent technology ensures the real-time data extensive computing-assisted smart health care sector. After that, the improvement of the health care sector is highly notified as a result, bioinformatics, telemedicine increment in massive level currently [2]. On the other hand, Wireless sensor networks define the physiological elements such as blood ECG, cholesterol, allergies, pressure, oxygen levels that help several healthcare issues [3]. The capabilities of devices and technologies used to treat critical diseases. The IoT systems in the healthcare sector acts a crucial role to transfer fundamental information besides developing the medical sector also medical. In addition, the system hits the evaluation of the economical segment also so that professionals, experts can provide authentic solutions with the help of IoT systems [4]. The research paper has shed light on some specific points such as a literature review covering the intellectual health care system with the help of IoT, techniques of IoT, and application of IoT in the health care system. The methodology section derives the whole research process

## RESEARCH ARTICLE

# Combining the advantages of AlexNet convolutional deep neural network optimized with anopheles search algorithm based feature extraction and random forest classifier for COVID-19 classification

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## Abstract

In this article, COVID-19 detection and classification framework based on anopheles search optimized AlexNet convolutional deep neural network for random forest classifier is implemented. Here, the COVID-19 dataset is taken from Joseph Paul Cohen database. Then, the input images are preprocessed with the help of fuzzy gray level difference histogram equalization technique (FGLHE) and fuzzy stacking technique for color enhancement and noise elimination in the input images. The FGLHE technique and fuzzy stacking technique are combined together and forms into stacked dataset image. This stacked dataset are trained with AlexNet convolutional deep neural network model and the feature packages acquired via the models are processed by the anopheles search algorithm. Subsequently, the efficient features are combined and delivered to random forest (RF) classifier. The proposed approach is implemented in MATLAB. The proposed ADCNN-ASA-RFC provides 91.66%, 69.13%, 34.86%, and 70.13% higher accuracy, 79.13%, 60.33%, and 63.34% higher specificity and 77.13%, 58.45%, 25.86%, and 55.33%, higher sensitivity compared with existing algorithms. At last, the simulation outcomes demonstrate that the proposed system can be able to find the optimal solutions efficiently and accurately with COVID-19 diagnosis.

## KEYWORDS

artificial intelligence, computed tomography, COVID-19, medical image and accuracy

## 1 | INTRODUCTION

The new COVID-19 (2019-nCoV) from Wuhan is presently spreading throughout the world.<sup>1-3</sup> Since the documentation of virus in late December 2019,<sup>4,5</sup> the number of cases from China that have been imported to other countries has been increasing, and the epidemiological landscape changes daily.<sup>6,7</sup> As complete cases of the single SARS-CoV-2 emerge throughout the world,<sup>8-13</sup> the entire eye has focused on the seafood market at Wuhan, China, from outbreak source.<sup>14-19</sup> Currently, COVID-19 is the main explanation of death internationally, with the main deaths found in the US, Spain, Italy, China, the United Kingdom, and Iran.<sup>20</sup> There are numerous kinds of COVID-19 and SARS-CoV-2 usually found in animals. COVID-19 is exposed on humans, bats, pigs, cat, dog, rodent, and chicken.<sup>21</sup> The COVID-19 symptoms are pharynges, headache, fever, and so on. Lately, artificial intelligence (AI) has been broadly utilized to accelerate biomedical research.<sup>29</sup> By in-depth



# Optimized Segmentation based Deep Learning Technique for Brain Tumor Classification

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## Abstract

The deadly tumours around the world is a brain tumour. This form of cancer occurs frequently in both children and adults. Of all human life's forms there are many different varieties, each with their own unique survival rate and appearance. The repercussions of incorrectly classifying the tumour brain will leads to death. As a result, early detection of the correct tumour type and grade is critical in determining the most effective course of treatment. An automatic classification and segmentation model for brain tumours is presented in this research. Once the input images are pre-processed, optimised Fuzzy C-Means technique (OFCM) is used for segmenting the tumors. Artificial fish swarm optimization is used to identify the ideal centroid for effective FCM segmentation. Then, a deep learning procedure is employed to categorize the tumours. Optimizing the weights of the deep learning structure utilising the Opposition-based Flower Pollination (OPF) method can increase the classification rate of the tumour detection procedure. MRI scans are used to conduct the tests, which are then analysed using a variety of criteria.

**Key Words:** Artificial Fish Swarm; Brain Tumor; Fuzzy C-Means; Opposition based Flower Pollination; Segmentation .

**DOI Number:** 10.14704/nq.2022.20.6.NQ22506

**NeuroQuantology 2022; 20(6):5029-5038**

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## Introduction

Around 100 billion nerve cells make up the human brain, a vast and complex organ that regulates the whole neurological system [1]. The nervous system's most important organ, the brain, is located in its core. As a result, any abnormality in the brain i.e. tumors of the brain could put human health at risk. There are two types of brain tumours: primary tumours and subordinate tumours, which are both uncontrolled and abnormal development of cells in the brain. In contrast to primary tumours, secondary tumours banquet to the brain via the bloodstream from other parts of the body [2]. Glioma and meningioma are two of the most deadly forms of brain tumours, and if they aren't identified early, they can lead to death [3]. Gliomas [4], the most frequent type of human brain tumour, are extremely common.

Tumors of the brain are classified by the WHO into

four categories [5]. There are three grades of cancer: grade 1, 2, and 3, where the grade 3 and grade 4 tumours are the most severe (e.g., glioma) (e.g., glioma). There are roughly 15 percent, 15 percent and 45 percent incidence rates for meningioma, pituitary and glioma tumours in clinical practise [6]. Depending on the type, size, and location of the tumour, there are a plethora of treatment options for treating brain tumours. There are no long-term negative effects from surgery for brain tumours at this time. [7]. Brain tumour diagnosis, growth prediction, and treatment can all advantage from involuntary segmentation and classification of medicinal pictures. An earlier uncovering of a tumour means a more rapid response to treatment, which increases the chance of survival for patients. The time and effort required to locate and classify brain tumours in huge medical picture databases, which are taken during ordinary clinical duties, is considerable [8-10].

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## Research Article

# Development of Rogers RT/Duroid 5880 Substrate-Based MIMO Antenna Array for Automotive Radar Applications

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Received 22 April 2022; Accepted 9 June 2022; Published 6 July 2022

Academic Editor: V. Vijayan

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In this paper, a novel  $2 \times 2$  multiple-input multiple-output (MIMO) antenna array with four patch elements is designed. The proposed antenna is the first dual band, operating at two prominent working frequencies: 24 (24.286–25.111) GHz and 77 GHz (75.348–79.688), of automotive radars. This structure is composed of two antenna modules colocated on a single substrate, whereas each module is made up of a corporate fed planar array of two elements. This attractive feature enables us to utilize the antenna in two different ways; either both modules serve as the transmitting/receiving antenna of a monostatic radar or one module serves as a transmitter and the other one as the receiver of a bistatic radar. Most of the existing autonomous radar applications operating at 24 GHz are going to become obsolete, and all countries have plans of shifting towards the 77 GHz band. Hence, our design is very attractive as it operates with the required performance in both the bands with another added feature of the MIMO structure. The placement of antenna elements is also optimized in terms of inter- and inraelement separation of greater than  $\lambda/2$  so as to ensure high diversity gain of 9.6 dBi. Moreover, the proposed antenna structure with only two antenna elements is able to achieve a high gain of around 11.8 dBi and 11.3 dBi at the dual operating modes of 24 GHz and 77 GHz, respectively. In addition to the above-mentioned benefits, this design also addresses mutual coupling reduction that is a common problem in MIMO structures by using complementary split ring resonator (CSRR) structures. State-of-the-art comparison with the recent literature shows that the proposed antenna has less number of antenna elements, an adequate gain, an excellent VSWR value, and high isolation.

## 1. Introduction

The revolution in the automobile industry is supported on a large scale by the developments in electronics, artificial intelligence, communication, and radar technology. All these technologies are highly in the mandate for the upgrade

of automotive cars/vehicles into a higher level. Thus, the highly automated vehicles (HAV) that incorporate various customer needs such as safety, flexibility to handle, money-saving, and luxury are in huge demand in the market. The above services can easily be provided by the innovation and implementation of suitable technologies in autonomous