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Table of Content

Title of Paper	Authors Name as per manuscript separated by comma	Page No.
Evaluation of CNN-BiGRU and CNN-BiLSTM Model for Fake Job Post Detection:A Deep Learning Approach	Sushilkumar Chavhan, Rajesh C. Dharmik, Sachin Jain	1-8
AI, Financial Technology and sustainable Investment in ESG funds in India: A Bibliometric Exploration	Durgesh Bahuguna, Rajesh Tiwari, Chandra Prakash, Bijesh Dhyani	9-13
Chromaticity discrimination using statistical analysis	Colaco AM	14-17
Development of Mini Seeker Robot: Automated Border Surveillance System	G. Karthik Reddy, M Raj Kumar Naik, Bandi Sampurna, R Deepak Varma, SVS Prasad	18-22
Determinants of Financial Technology (Fin-Tech) adoption in agrarian economy of developing nation: A bibliometric analysis	Akhilesh Sharma, Arvind Mohan, Amar Johri	23-27
Impact of Artificial Intelligence to influence Consumer Behavior towards Online Pharmacy: A bibliometric analysis of Perception Studies	Kapil Ahalawat, Rajesh Tiwari, Akhilesh Sharma	28-33
Fall Detection System for Elderly Wellness using LSTM and SVM	Balaji K, Sangeetha Rodda, Supraja Nidumolu, Pradeep Saidanna, Likhith Putti	34-39
Experimental Evaluation Unified Payment Interface (UPI) Fraud Detection System using Elevated Deep Learning Methodology	Tamilselvi M, Rowsonara Begum, Krishnamoorthi K, Jayant Giri, D Sheela, Mohammad Omar Sabri	40-45
A Distinctive Centralized Street Light Fault Monitoring System Embedded with Reconfigurable WSN	Shyam M., Madav Mahesh R. A., Sakthi Santhosh A. B., Sanjay P.	46-52
Classifying Disease Diagnosis through Tongue Image Analysis Using Artificial Intelligence and Image Processing	Dushyant V Mankar, Dr. P S Choudhary	53-58
Development Of Tongue Image-Based Diagnostic System Using Deep Convolutional Fused Features And Machine Learning	Dushyant V Mankar, Dr.P S Choudhary	59-64
An Analysis of Recommendation System Based on Multimodal Emotion Detection using facial expression and voice modulation	Kiran R. Gavhale, Ujwalla H. Gawande	65-70
Smart Medicine Reminder Box	Chetan Gode ,Milind Narlawar ,ManasThakare ,Nakul Lakade ,Pradnya Parate,Sanskriti Kayarkar	71-74
Soulmind: Mental Health Chatbot with Anxiety Prediction	Nishtha Raut,, Bhagyashree Kalambe, Amey Salvi, Himanshu Kothari, Namita Pulgam,	75-81
Comprehensive Study of Face Verification in Voting System	Himanshu R. Katrojwar, Saloni Deshmukh, Aishwarya S. Parwekar, Rahul Agrawal, Chetan Dhule, Nekita Chavan Morris	82-86
Modeling Precipitation Patterns with Time Series AutoRegression Techniques	Rishit Kashyap , Harsh Murme , Rahul Agrawal , Chetan Dhule , Nekita Chavan Morris	87-91
IOT Based Monitoring and Controlling Mechanism For Orange Orchard	Pratibha Waghale, Lalit Damahe, Swati Gaikwad , Chanchala Tripathi, Shilpa Dhopte, Amruta Paul	92-100
Power Sharing Capability of Fast Charging Stations for Electric Vehicles	Pranay S. Shete, Dr. R. M. Moharil	101-105
Hybrid Taguchi Grey Relational Analysis (TGRA) Method for Multi-Optimization of Machining Process Factors	Prashant D. Kamble ,Shilpa B. Sahare , Heena D. Mehta	106-109
Crop Health Detector Development Using Q- Learning And Afta- A Survey	B. Seshasayee, K. Sanjana, M. Sankar, B. Balakiruthiga	110-115
Smart Charging Techniques for Intelligent EV System: An Overview	Swati Arora, Abinash Singh, Vibhor Chauhan	116-121
Increasing Efficiency of Solar Panel Using Movable Reflector	Bharat S Sudame, Adarsh Ambare, Priyanshu Tandulkar, Arya Sadawarti, Nikita Kshirsagar, Aniket Bhiwankar	122-126
Prediction of Grapevine Leaf Identity with DenseNet121	Vijay Madaan, Neha Sharma	127-131
Unmasking Deception: A Comprehensive Comparative Analysis of Machine Learning Methods for Detecting Fake News in Social Media	Kaviya P, Sudharsana I	132-136
Compact AMC Antenna For Terrestrial Earth Exploration, Meteorological Satellites	Sarojini Naik, Ankita Avthankar, Sanju Purohit, Shital Patil, Vishal Borate, Yogesh Mali	137-142
FPGA Implementation of an Efficient Hybrid Multiplier: A VLSI Architecture Utilizing Hybrid Adder Technology	Bala Sindhuri Kandula, G. Challa Ram, S. Koteswari, P Srinivasulu, Thathapudi Kamala Kumari, Pampana Srinivas	143-148
Substantial Advancements in DC-DC Converters for Sustainable Future	Abinash Singh, Madhur Chauhan, Mamatha Sandhu, Gurinder Singh	149-154
India's Cooling Demand: Sustainability Meets Consumer Trends	Abinash Singh, Dhawan Singh, Harshit Thakur, Aditi Thakur	155-160
Review on Evolution of Vehicle Detection Methods in Computer Vision for Surveillance	Ekta Ukey, Satishkumar L. Varma	161-166
Hybrid Machine Learning Based Predictive Model To Improve Cloud Application Performance In Cloud Saas	Rushikesh Burle, Sanskruti Gaurkhede ,Palash Goursheetiwar, Sakshi Izankar, Swapnil Gundewar, Utkarsha Pacharane	167-172
Sales and Inventory Demand Forecasting Using Machine Learning	Kumar P , Vijayaraj A , Senthil Pandi. S , Venkatesh Prabhu Balakrishnan	173-178
Lip Reading System Using Deep Learning	Kishor Bhojar,Warsha Siraskar, Ritesh Dedmuthe, Chetan Nasre, Ankita Lokhande, Rohit Bhabore	179-184
Book-Bot – An AI Powered Library Assistance Tool	Mrudula Nimbarte, Nilay Prashantrao Manekar, Divya Shivhare, Ketki Jain, Gurjyot Singh Raina, Kushal Badjate	185-191
Enhancing Glaucoma Diagnosis With CNN Models-A Vision- Centric Approach	Asha Bharathi S, Hamsa S, Nikshitha S, Navya P Vernekar, Shankara C	192-198

Smart Aquarium Management System using Computer Vision and Image Recognition Technology	Dr Rashmi Patil, Mrs Suwarna Kadam, Jaideep Bisen, Janhavi Chati, Kshaunish Borkar	199-203
A Novel Approach for Translating Kharosthi Script Text into Pali Language	Sangita Gudadhe, Aashish Bardekar, Amitkumar Ranit	204-207
Performance Analysis of CMOS Full Adder using Machine Learning	Kausar Fakir, Sudhakar Mande	208-213
Novel Approach of Digit Serial Multiple Constant Multiplication in DSP Applications	Rajendra M.Rewatkar Chetan G. Puri Amit A. Gudadhe Shubhangi V. Rathkantiwar Nitin Wange	214-219
An Investigation into the application of chaotic map encryption for image transfer in an IoT framework	Reenie Tanya, Balika J Chelliah	220-225
On-chip True Random Number Generator using System Monitor	Pravin Zode, Pradnya Zode, Pankaj U. Joshi	226-228
Enhancing Tourism & Exploration through Advanced Mobile Technology and Machine Learning	Sarika Khandelwal, Harsha Vyawahare, Prasanna Palsodkar, Shaleen Bhatnagar	229-234
Ensemble-Based Computer-Aided Pneumonia Identification on Chest X-Ray Images	Mirza Moiz Baig, Rahul D. Gajbhiye, Shrikant V. Sonekar, Supriya Sawwashere	235-240
An Approach for Integrating Neo4j in a Dual-Model Database System	Harsha Vyawahare, Sarika Khandelwal, Prasanna Palsodkar, Seema Rathod, Sheetal Dhande, Pradnya Vikhar, Prachi Palsodkar	241-245
Applications of artificial intelligence in solid waste management	Gauri S. Deshmukh, Praveen Kumar	246-251
Performance Analysis of VLSI Architecture of Dadda Multiplier Using Divide and Conquer Strategy with Approximate Adders	Bala Sindhuri Kandula, Raghumandala Devi, Muddala Kamakshi Devi, Pilli Gamyta Geethika, Prodduturi Hitesh, P Y N S Vara Prasad	252-257
IoT-Enabled Solutions for Efficient Irrigation in Remote Agricultural Villages	M. S. Kavitha, K. Kannan, Bharath Singh Jebaraj, Sushmitha S. A. Sumaiya Begum, Vivekrabinson K	258-262
Deep Learning Approaches for Evaluating the Quality of Fruits and Vegetables	Gaurav Divtelwar, Aparna Bondade, Sandhya Patil, Dhananjay Bhagat, Charvi Suri	263-268
Empirical evaluation of QoS-aware block chain-based security models from a statistical perspective	Hitesh Gehani, Shubhangi Rathkantiwar, Dr. Rajendra M. Rewatkar	269-274
Unlocking the Visual Symphony: Analyzing Cymatic Patterns of the Gayatri Mantra through Image Analysis	Bhaurao Shankarrao Badak, Ajay Anil Gurjar, Nayana Ganesh Gavhale	275-280
Design of an Improved Model for Soil Parameter Monitoring and Health Prediction Using Machine Learning and Data Fusion Techniques	Anagha Choudhari, Dinesh Bhojar, W. P. Badole	281-286
Ant Colony Optimization Driven Failure Prediction in Industrial Internet of Things	Sarika Mane, Makarand Kulkarni, Sudha Gupta	287-292
Dysarthria Voice Enhancement Using Novel WPT-TDO Algorithm	Kapil Kotangale, Yuvraj Parkale, V.N.Patil	293-297
LSTM-Based Deep Learning Approach To Analyze The Impact Of COVID-19 On Auto And Pharma Sector Stocks Of Nifty50	Ajaykumar K. Kakde, Manisha P. Dale	298-304
Machine learning approach for detection of DDoS attack in cloud environment	Harshala Shingne, Kartik Vhonale, Pratham Shrivastava, Purva Gholse, Rahul Barlinge, Mohammad Amash Alam	305-311
Enhancing Crop Disease Detection Systems with Explainable AI Techniques for Deep Learning Models Using Spectral Imaging	Gajanan Ankatwar, Chitra Dhawale	312-319
Prediction of Nusselt Number in Natural Convection Heat Transfer of Vertical Helical Coil Using Machine Learning	Ganesh Sahadeo Meshram, Gloria Biswal	320-325
Diabetic Retinopathy Diseases Classification from Fundus Images using Deep Learning	Dr. Preeti P. Kale, Dr. U. B. Shinde, Dr. Syed Sumera Ali, Dr. Devendra L. Bhuyar, Mr. Hemant B. Mahajan	326-331
A Miniaturised Honeycomb -Shaped Frequency Selective Surface (FSS) for mmWave 5G Applications	Praveena V, Tamilarasi M and Mohan C	332-335
Advanced Deep Learning Architectures for Brain Tumor Detection: An Evaluation of EfficientNet, ResNet and Xception	Vedant Gabhane, Rahul Agarwal, Chetan Dhule, Nekita Chavan Morris	336-341
Video based Noncontact Heart Rate Estimation with Scale Invariant Feature Transform and Nonlinear Mode Decomposition	Hemlata G. Biradar, Jayanand P. Gawande	342-347
Enhanced Resource Optimization Methods for Device-to-Device (D2D) Communication in Next Generation Wireless Networks	Sapana Dhanvijay, Rajesh Kumar Rai, Vijeta Yadav, Ghizal Ansari	348-355
Minimally Invasive Therapy for Retrieval of Ingested Foreign Bodies in GI Tract using Magnetic Slime	Ushasri Akkanapalli, Bharadwaja Reddy Gundam, Shrawanthi Kandenelly, Kumar Kandukuri, Shaja Khan	356-360
An Augmented Reality-based User Interface Design for integrating Immersive Technology in STEM Education	Deepthi Prit Kaur, Amit Kumar	361-366
Machine Learning Models for Predicting Resale Value of Car	Aditya Sherki, Parag Bandhate, Tejas Thete, Faizan Habib, Piyush Zambre, Kishor Bhojar	367-374
Sports Recognition in Videos using Deep Learning	Ayan Sheikh, Chetan Kuhite, Sanket Chamate, Vedant Raut, Rajeev Hudar, Kishor K. Bhojar	375-379
Band Notch Compact for the Two-Port MIMO Antenna for the UWB Applications	Mr. Shivanand Konade, Dr. Manoj Dongre	380-387
Flood Prediction Map using QGIS and ML- Case Study for Barpeta District Assam	Lalit Damahe, Sagar Lachure, Kush Thakare, Vaishnav Dekate, Vedant Shivde, Sanskruti Gedam	388-393
Electrocatalytic Performance of MWCNT on GCE for Highly Selective dopamine and Uric Acid Sensing	Parthasarathy P	394-398
Testing the Accuracy of Fibonacci Retracement Levels using Artificial Intelligence	Pratik Kodmalwar, Leena Kapse, Amol Mashankar, Kumar Mansukhani, Amruta Mahalle, Nilesh Bhosale	399-404
Multi-Keywords based Fully Homomorphic Encryption and Data Classification for Cloud Security and Privacy	Kooragayala Sukeerthi, Dr. R. Kesavan, S.A.Kalaiselvan	405-411
Virtual Zone Construction for Clustering Process in Mobile Wireless Sensor Networks	B. Swathi, Dr. M. Amanullah, S.A.Kalaiselvan	412-418
Exploring the Landscape of ChatGPT Research: A Bibliometric Study Using Scopus Database	Parul Dubey, Sumit Prasad, Dr. Lubhawani Tripathi, Rashmi Sharma, Dr. Sampada Mashirkar, Shilpa Ghode	419-424
Spinal Column Needle With a Force Feedback: Introductory Study	Samir Morad, Kiran Hayer, Ameer H.Morad, Taha Mehraj	425-429

Source Camera Identification of Images Using Transfer Learning	Kapil Raisinghani, Yash Mohan, Kavita Jhaharia	430-434
Effective Positioning of Shear Wall in Multistorey Building in Medium Soil Condition using Response Spectrum Analysis	Vaidehi Wasalwar, Vivek Jayale	435-440
The Role of IoT in Enhancing Wireless Sensor Network Applications: A Comprehensive Analysis	Ms. Sonia Singh and Dr. Neha Gupta	441-446
A DVCC based Realization of Optimized Fractional Step Low Pass Filter	Shibendu Mahata, Soumen Mallick, Rahul Kumar Tanti, Balaram Halder, Piyush Dutta, Subhajit Hati	447-452
Modelling and Synthesis of a Ring Oscillator based True Random Number Generator using Open-Source EDA Tools	Deepti Khurge, Sheetal Bhandari, Gaurav Joshi, Harshal Khairnar, Yash Meshram, Gaurav Patil	453-456
Smart Water Management System for Housing Societies	Abha Marathe, Ayush Lodha, Omkar Lolage, Piyush Lodha, Leevan Herald	457-461
Implementation of Web Based Intelligent System for Diabetes Prediction using Machine Learning	Abhishek Rana, Parampreet Kaur	462-467
Assessing Protection Systems for Solar PV Penetration Across Different Locations to Enhance Grid Stability and Reliability	P. S. Patil, Dr.R. M. Moharil, A. S. Lilhare	468-473
Controlling Electric Switches Using IoT Devices as a Smart Switch via Android Application	Pradnyawant M. Gote, Rasika Hajare, Karan Urkude, Mohar Warbhe, Yash Pachghare, Tejas Pisal	474-479
Determination of Properties of Soil with Ultrasonic Pulse Velocity	Jayant Manohar Raut, Kashisha Prabhakar Kapse, Sonal Bhagwan Dhanvijay, Kamlesh Prashant Thawkar, Pawan Keshaorao Hinge, Tejaswi Ajay Sahare, Tanushree Damodhar Ramteke, Rahul Parasaram Rathod	480-484
Corrosion Resistance Strategies for Biomedical Implants: A Comprehensive Review	Prajwal Bandre, Subodh Daronde, Trishul Dhale	485-491
Optimized Medical Data Synchronization using Dual Serial Communication Interfaces with Buffered Data Transfer	Alpesh Dongre, Chaitanya Nemad, Yogita Chitriv, Prachi Palsodkar,	492-496
Stock Prediction Using Dual Analysis of Candlestick Chart Pattern	Vilas Alagdeve, Pradeep Karule, Prasanna Palsodkar	497-501
Performance comparison of 4,8 and 16-bit ALU in different FPGA boards	U. Harsha Vardhan Reddy, Devadarsh C H, Nived P V, Pooja Dileep, Lakshmi Nanda, Geethu R S	502-506
Innovations and Applications of Generative Adversarial Networks (GANs)	Meher Langote, Nikita Zade	507-512
Classification of the oral mucosal lesions using the principle component analysis based naive Bayes classifier: fluorescence spectroscopy as a detection device	Pavan Kumar, Hemlata Vikrant Ganvir, Vikrant Yashwant Ganvir, Shashikant Rathor, Dipti V Jamkar	513-517
Smart Hydroponic System: Real Time Monitoring and Early Plant Disease Detection Using IOT and Machine Learning.	A. D. Tijare, Satwika Athena, Sahil Tonge, Pratik Kamdi, Anshul Gajbhiye, Harshal Bobade	518-521
Extraction Of Photoplethysmography Signal For Heart Rate Estimation Using Smartphone Camera	Asawari K. Chinchanikar, Manisha P. Dale	522-525
Anaerobic Digestion of Napier Grass and Cow Dung: A Sustainable Approach to bio-methanation	Payal Jayale, Harshal Warade, Vivek Jayale	526-531
MFANEDH: Multimodal Fusion of MRI, PET, CT, and Ultrasound Using Advanced Neural Architectures for Enhanced Early Detection of Heart Cancer	Kiran Khandare , Gaurav Divtelwar , Charvi Suri , Aparna Bondade	532-537
Waste Management A Telegram – Integrated Smart Garbage Bin	Rajakumari S T, Sritama Roy	538-543
Design and Implementation Of Microwave Oven Using Verilog	Nived P V, Gowshith S, Rajesh Kannan Megalingam	544-549
Innovative Approaches for Non- Invasive Hemoglobin Detection: A Comparative Analysis	Megha Chakole, Shrutika Janbandhu, Rutuja Saharkar, Tejasvini Lichade, Sanjay Dorle, Roshan Umate	550-554
Single-valued neutrosophic graphs for energy analysis of various power plants	A. S. Sasipriya	555-559
Mobile Applications Powered by AI for Early Detection of Chronic Disease	Mawuli Apetorgbor, Supriya Narad, David Raymond, Nyamador Amanda Fortune, Abdulrahman Abba Konto, Martin Doe	560-565
Experimental Investigation of Concrete Pavers by Partial Replacement of Fine Aggregate with Crushed Seashell	Vivek Jayale, Payal Jayale, Ashwini Patil, Ritika Mohadikar, Pratik Wethe, Aachal Tapase	566-570
Predictive Modeling of Concrete Compressive Strength Based on Drilling Parameters	Prashant Pande, Samruddhi Mahakalkar, Sneha Kendre, Lalit Ingole, Pratham Dhotkar, Salil Karmarkar, Yash Kamle	571-575
Enhancing Integrity in Criminal Investigations with Secure Evidence Attachment	D. Rosy Salomi Victoria, S. Roselin Mary, K. Somasundaram	576-581
Performance of Drives for High Power Applications of Petrochemical Industries	Uttkarsh Tripathi, Shikha Singh	582-585
Fuzziness based Multimodal Semi-Supervised Learning for Alzheimer's Disease Diagnosis	Sanket Kasturiwala, Rushikesh Bankar	586-591
GDVM: A Deep Learning assisted Fetal Health Prediction System using Gradient Distance Vector Model	G. Ramkumar, M. Swarna, Madhini M, P Kalpana Devi, Pallavi Giri, Ala'a Al Sherideh	592-596
An Intensive Model for Wheat Crop Disease Prediction based on Hybrid Deep Learning Principle with Image Processing Support	Govindaraj Ramkumar, M. Swarna, R S Vijayashanthi, Hubert Mary, Pallavi Giri, Ayman Amer	597-601
A Robust Prediction of Online Social Network Influencers by using Elevated Deep Learning Strategy	S.Agnes Shifani, R Sathishkumar, M Priscilla, T Jayakumar, Neeraj Sunheriya, Maram Y Al-Safarini	602-607
Experimental Evaluation of BigData Analytics to Improve Communication Security and Privacy Enrichment using Cybersecurity Logics	S Agnes Shifani, M. Swarna, S. Sangeetha, T Jayakumar, Rajkumar Chadge, Ahmad Abdelhafiz Ali Samhan	608-613

HNLS: Designing a Robust Model for Human Action Recognition based on Postures by using Hybrid Neural Learning Strategy	Govindaraj Ramkumar, Hasina Nasrin, M Ramya, Jayant Giri, N P G Bhavani, Ahmad Abdelhafiz Ali Samhan	614-618
VLC: A Robust and Highly Secured Data Communication Service Establishment using Visual Light enabled LiFi Technology	G. Ramkumar, J. Megala, S. Ramesh, S.Satheeshkumar, Jayant Giri, Hani Attar	619-623
Investigational Study on Creep Performance of Aluminum Alloy 6061-T6 Using Creep Indentation Test	T. Sathish	624-628
Preparation and characterization of Cellulose/SiO ₂ -based Graphene oxide composite films with improved mechanical properties	T.Sathish	629-633
Thermal Properties of Jute and Hemp Fiber Composites Reinforced with CuO Nanoparticles	T.Sathish	634-638
Thermal and Mechanical Enhancement of Sisal and Banana Hybrid Fibers through ZnO Nanoparticle Integration	T.Sathish	639-643
Effect of Silicon Carbide Nanoparticles on the Mechanical and Thermal Enhancement of Bamboo and Ramie Fiber Reinforced Composites	T.Sathish	644-649
Empirical Possibilities of Social Network Privacy and Security Enhancement to Improve Data Communication Efficiency	T. P. Ramachandran, V. Sathya, Sharon Sweeti, R.B.Revathi, Rajkumar Chadge, Mohammad Omar Sabri	650-655
Empirical Evaluation of Phishing Attack Identification over Websites by using Intelligent Deep Learning Principle	Anitha G, Mouleeswaran S K, Dickson Irudayaraj V, G B Santhi, Rajkumar Chadge, Hani Attar	656-661
A Logical Evaluation of Tuberculosis Disease Prediction using Artificial Intelligence (AI) enabled Learning Methodology	Govindaraj Ramkumar, C R Bharathi, Jayant Giri, T P Rama	662-666
Experimental Evaluation of Staff Ability and Performance based on Depression Level Analysis using Machine Learning Principle	Anitha G, Mouleeswaran S K, M Swarna, G B Santhi, Pallavi Giri, Mahmoud Odeh	667-671
Improving the Electrical Machine Efficiency Using Variable Frequency Drive Compared with Multi-Level Inverter by Reduction of Power Loss	G. Ramya, Lalitha B, Sathish Kumar D, Rajkumar Chadge, Mohammad Rasmi Al-Mousa, S. Ravi	672-674
A Novel Image Processing Scheme Design to Predict Autism Spectrum Disorder using Deep Learning Mechanism	G. Ramkumar, N Suriya, S B Mohan, Pallavi Giri, P Shayamala Bharathi, Ala'a Al Sherideh	675-679
Effect of silane treatment for Izod and hardness properties of jute/kenaf glass fiber reinforced with Titanium dioxide	Thanikodi Sathish, Rathinasamy Saravanan, Solairaju Jothi Arunachalam, Jayant Giri, Mahmoud Odeh	680-683
Optimization of Interlaminar Shear Strength of the Jute/Kenaf/Glass with MWCNT using RSM	Thanikodi Sathish, Rathinasamy Saravanan, Solairaju Jothi Arunachalam, Jayant Giri, Ayman Amer	684-689
Optimization of Interlaminar Shear Strength of the Jute/Kenaf/Glass with Silicon Dioxide using RSM	Thanikodi Sathish, Rathinasamy Saravanan, Solairaju Jothi Arunachalam, Jayant Giri, Ayman Amer	690-695
Enhancing Computer Vision Using Vision Transformers and Hybrid CNN-Transformer Architectures	Nongmeikapam Thoiba Singh, Sandeep Sing Kang, Kusum Lata	696-703
Enhancing Pervious Concrete with Agro-Industrial Waste: A Sustainable Approach to Water Quality Improvement and Mechanical Optimization	Sanket Gajanan Kalamkar, Sanjay P. Raut, Pritam Hatwar	704-709
Hardening Characteristics of 16MnCr5 Metals for Engine Block	Meikandan Megaraj, M. Chandrasekaran, P. Umamaheswarrao, Jayant Giri, M. Anish, Ahmad Abdelhafiz Ali Samhan	710-715
Experimental Investigation on Strength Characteristics of Cement by Using Nano synthesis Expanded Clay Aggregate and Silica Fume	Kalyana Chakravarthy Polichetty Raja, Sharmila G, A.Geetha Selvarani, Jayant Giri, M. Anish, Khaled Al-Qawasmi	716-722
Bibliometric Exploration of Healthcare Automation and Robotics through the Lens of the Scopus Database	Pummy Dhiman, Swati Singh, Anupam Bonkra, Arun Kumar Rana, Jayant Giri, Mohammad Omar Sabri	723-728
Effect of hydroxyapatite incorporated with polyacrylamide polymer composite – Chemical and thermal analysis	T. Sathish, Jayant Giri, Ala'a Al Sherideh	729-733
Enhanced reinforcement of filler in polyurethane foam – Mechanical and Thermal Properties	T. Sathish, Jayant Giri, Ala'a Al Sherideh	734-738
Effect of thermal and mechanical characterization of titanium dioxide incorporated in polyetheretherketone materials	T.Sathish, Jayant Giri, Hani Attar	739-743
Enhance the Properties of Hybrid Fiber Composites with TiO ₂ Nanoparticles	T. Sathish, Jayant Giri, Hani Attar	744-748
Effects of MWCNTs+SiO ₂ inclusions on the quasi-static compression and hardness behavior of basalt/E-glass fiber/polymer hybrid nanocomposite	T.Sathish, V.Boobalan, Pallavi Giri, Hani Attar	749-754
Enhancing Flexural Performance of Basalt/Glass Fiber Hybrid Nanocomposites with MWCNTs+SiO ₂ Nanoparticles by Box-Behnken Design of RSM	T.Sathish, V.Boobalan, Pallavi Giri, Mohammad Rasmi Al-Mousa	755-761
Investigation Coating on Carbon Steel using Nickel Polydimethylsiloxane Composite in Corrosive Environment	Thanikodi Sathish, Rathinasamy Saravanan, Jayant Giri, Mohammad Rasmi Al-Mousa	762-767
Impact of Silicon dioxide (SiO ₂) on the properties of Kenaf and Jute Fiber Composites	Thanikodi Sathish, Rathinasamy Saravanan, Jayant Giri, Khaled Al-Qawasmi	768-773
Statistical study of thermal analysis in solar air heater system using inclined discrete rib	Thanikodi Sathish, Rathinasamy Saravanan, Jayant Giri, Khaled Al-Qawasmi	774-778
Effect of TiO ₂ in Jute/Kenaf/Glass Composite for Interlaminar Shear Strength Using RSM	T. Sathish, R. Saravanan, S. Jothi Arunachalam, Jayant Giri, Ahmad Abdelhafiz Ali Samhan	779-784
Designing a 4 DoF Manipulator and a Production Line for Lifting and Transporting Pieces	Mohammed Amer, Zeineddin Yasin, Samer Alsadi, Tareq Foqha, Ahmad Abdelhafiz Ali, Jayant Giri, Neeraj Sunheriya, Rajkumar Chadge	785-792

Reconfiguration of the Electrical Network at Arab American University for Improved Efficiency	Aya Herzallah, Aya Abu Shمله, Osama Omari, Samer Alsadi, Tareq Foqha, Mohammad Rasmi Al-Mousa, Jayant Giri, Neeraj Sunheriya	793-799
Study of Thermo-Mechanical properties of Particle Reinforced Aluminum Matrix Composite	Deepak Kumar Yaduwanshi, TsgayTikubet, Mohammad Omar Sabri, Meikandan Megaraj, Jayant Giri, M. Anish	800-806
Real-Time Driver Monitoring System Using Computer Vision to Detect Drowsiness for Enhanced Traffic Safety	Sneha C I, M. Rohini, S. Oswalt Manoj, Jayant Giri, Mahmoud Odeh, Neeraj Sunheriya	807-812
Design of an Improved Model Using Hybrid GA-CNN and DQN for Real-Time Cybersecurity Enhancement	Smita Dhote, Priya Dasarwar, Shruti Thakur, Ganesh Khekare, Dr. Gayatri R. Katole, Aman Urganlawar	813-818
Enhancing Privacy Protection by MVQQ and PBAA in VANET with AI Technique	A. Venkateswarlu, Narayana Rao Appini	819-823
Use Of Yolo Architecture With Real Time Object Detection For The Improvement Of Facial Recognition By Using Marker Controlled Watershed Approach In Deep Learning	Shubhangi D.C, Syeda Maliha Hashmi	824-830
Deep Learning Models For Assessing Individuals With Mild Cognitive Impairments	Shubhangi D.C, Madeeha Tahoor	831-837
Emotion Classification in Dogs By Deep Learning	Shubhangi D. C, Saniya Fatima	838-844
Enhancing User Interaction On Discord With Multimodal Generative AI	Vijay Wath, Vaishnavi Deogade, Yadhresh Vyawahare, Gagan Loya, Megha Chakole, Yogita Dubey	845-849
Optimizing X-Band Low Noise Amplifier: Design Challenges, Topologies and Technological Insights	Payal Bagde, Sonali Joshi, Sanjay Dorle, Payal Ghutke, Wani Patil and Megha Chakole	850-855
A Novel Static Wireless Charging and Payment Mechanism for Electric Vehicles	Megha Chakole, Prathamesh Naidu, Manas Sakhare, Shreyash Umale, Siddhant Rakesh, Aniket Pathade	856-860
Predicting The Magnetic Poles' Shift using Machine Learning	Amruta Tapas Paul, Lalit Damahe, Bhagyashree Hambarde, Aman Urganlawar, Sudhanshu Nerkar, Aditi Bhardwaj	861-866
Smart IoT-Based System for Real-Time Monitoring and Management of Normal Saline Levels in Healthcare Facilities	Nikhil Mangrulkar, Sagarkumar Badhiye, Sampada Tagde, Sachin Patil, Rajsinh V. Mohite, Sachin Chaudhary	867-871
Assessing Water Conservation in Government Washrooms: A Case Study of Water Power Saver (WPS) Usage in Nagpur	Prachi Gawande, Yogesh Kale, Dr. Ashutosh Bagade	872-877
An Efficient Pre-treatment and Machine Learned Framework for Detection of Spoofed Faces	Vijay V. Chakole, Dr. Swati R. Dixit, Dr. P. T. Karule, Poonam T. Agarkar, Prachi Palsodkar, Prasanna Palsodkar	878-884

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A DVCC based Realization of Optimized Fractional Step Low Pass Filter

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Abstract—Realization of fractional-step low-pass Butterworth filter (FSLBF) using a differential voltage current conveyor (DVCC) is presented. To approximate the FSLBF characteristic, the coefficients of three different filter transfer functions are optimally determined using the Craziness-based Particle Swarm Optimization (CRPSO) algorithm. Minimum absolute pole angle, -3 dB frequency response, squared magnitude error, etc., of the FSLBFs are evaluated. Simulations verify the efficacy of DVCC-based realizations for the designed frequency filters.

Index Terms—fractional order circuits, fractional step filter, Butterworth filter, craziness-based particle swarm optimization, differential voltage current conveyor

I. INTRODUCTION

Fractional-order systems are governed by fractional differential equations, which use derivatives and integrals of non-integer order as core operators [1]. This mathematical framework, known as fractional calculus, has diverse applications [2]–[4].

A fundamental element in building fractional-order analog circuits is the constant phase component, such as a fractional-order capacitor (FOC) [5]. Given the lack of commercially available FOCs, researchers have developed approximations using R-C ladder networks; one notable approach is the Foster-II network, illustrated in Fig. 1 [6]. Realization of fractional filters that employ the FOC [7], FOC emulator [8], and rational approximation technique [9] have been published in the literature.

FSLBFs offer a gradual stopband attenuation of $-20(n+\alpha)$ dB/dec, where α ranges between 0 and 1 [10]–[13]. For filters of order $1 + \alpha$, with a pole-frequency ω_0 , approximation can be achieved as described in equations (1)–(3).

$$H_A^{1+\alpha}(s) = \frac{1}{(s/\omega_0)^{1+\alpha} + k_{1A}(s/\omega_0)^\alpha + k_{2A}} \quad (1)$$

$$H_B^{1+\alpha}(s) = \frac{1}{(s/\omega_0)^{1+\alpha} + k_{1B}(s/\omega_0) + k_{2B}} \quad (2)$$

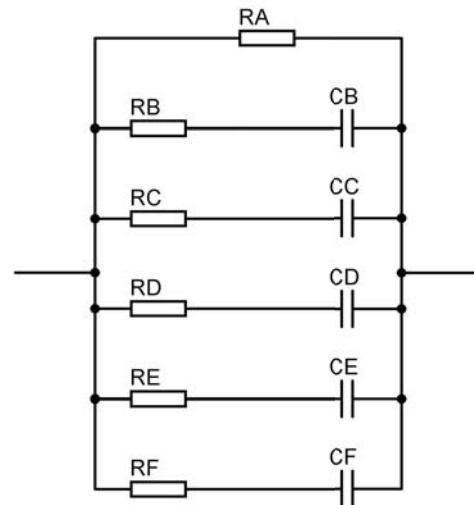


Fig. 1. A Foster-II network.

$$H_C^{1+\alpha}(s) = \frac{1}{(s/\omega_0)^{1+\alpha} + k_{1C}(s/\omega_0)^{(1+\alpha)/2} + k_{2C}} \quad (3)$$

where k_{1A} , k_{2A} , k_{1B} , k_{2B} , k_{1C} , and k_{2C} are the coefficients of the filter functions.

This study introduces the application of the CRPSO algorithm [14] to optimize filter design coefficients, specifically k_{1A} , k_{2A} , k_{1B} , k_{2B} , k_{1C} , and k_{2C} , for the first time. The goal is to reduce the discrepancy between the theoretical and actual magnitude responses of the proposed FSLBFs. Evaluation criteria include stability margin, error within the design frequency band, -3 dB cutoff frequency, and roll-off characteristics. The designs for orders 1.1, 1.5, and 1.9 are realized using DVCCs. Monte Carlo simulations further assess the impact of component tolerances on circuit performance.