

Object Detection in a UHD Video Stream in Real-Time Using HOG+SVM on a System-on-chip FPGA

Nizar M. Soufian, David Winters, Hakan Khan

1. Palestine Polytechnic University, Technology department, Palestine
2. Computer Science and Engineering, Shivalik Group of Collegers, Dehradun, 248001,
India
3. Department of Industrial Technology Engineering, Turkish-German University, Istanbul
34820, Turkey

Emails: prof.desoky@gmail.com, jcsiseditor@gmail.com, hakankhan24@mail.com

Abstract

Object recognition is a fundamental part of many different kinds of vision systems. For instance, advanced driver assistance systems (ADAS) and advanced video surveillance systems (AVSS) both make use of pedestrian detection. The majority of detectors, including those in the YOLO (You Only Look Once) family, currently use deep convolutional neural networks. However, because of the high computational complexity of these systems, they are unable to interpret a very high-resolution video stream in real time, which is especially problematic given the constrained energy budget they operate under. In this research, we offer a hardware implementation of the well-known pedestrian detector that uses HOG (Histogram of Oriented Gradients) feature extraction and SVM (Support Vector Machine) classification. Both of these techniques were used to analyze the data. Real-time processing of 4K-quality video at 60 frames per second is possible with our system when it is powered by an AMDXilinx Zynq UltraScale+MPSoC (Multiprocessor System on Chip) device. 4K stands for ultra-high definition, and its pixel dimensions are 3840 by 2160. The device is sensitive enough to identify a person walking on a single scale. The findings that were obtained provide further evidence that reprogrammable devices are very suitable for use in the real-time deployment of embedded vision systems.

(Keywords:)

Histogram of Oriented Gradients , Support Vector Machine , SoC FPGA , 4K , UHD ,
pedestrian detection, real-time vision systems

REQUEST FOR FULL TEXT

REFERENCES

- [1] El-Kenawy, E. S. M., Ibrahim, A., Mirjalili, S., Eid, M. M., & Hussein, S. E. (2020). Novel feature selection and voting classifier algorithms for COVID-19 classification in CT images. *IEEE Access*, 8, 179317-179335.
- [2] El-Kenawy, E. S. M., Eid, M. M., Saber, M., & Ibrahim, A. (2020). MbGWO-SFS: Modified binary grey wolf optimizer based on stochastic fractal search for feature selection. *IEEE Access*, 8, 107635-107649.
- [3] Saber, M., & Elkenawy, E. M. (2020). Design and implementation of accurate frequency estimator depend on deep learning. *International Journal of Engineering & Technology*, 9(2), 367-377.
- [4] El-Kenawy, E. S. M., Mirjalili, S., Ibrahim, A., Alrahmawy, M., El-Said, M., Zaki, R. M., & Eid, M. M. (2021). Advanced meta-heuristics, convolutional neural networks, and feature selectors for efficient Covid-19 x-ray chest image classification. *Ieee Access*, 9, 36019-36037.
- [5] El-Sayed Towfek, M., & El-kenawy, M. S. (2019). Reham Arnous. An Integrated Framework to Ensure Information Security Over the Internet. *International Journal of Computer Applications*, 178(29), 13-15.
- [6] Ibrahim, A., & El-kenawy, E. S. M. (2020). Image segmentation methods based on superpixel techniques: A survey. *Journal of Computer Science and Information Systems*, 15(3), 1-11.
- [7] Ibrahim, A., & El-kenawy, E. S. M. (2020). Applications and datasets for superpixel techniques: A survey. *Journal of Computer Science and Information Systems*, 15(3), 1-6.
- [8] Ibrahim, A., & El-kenawy, E. S. M. (2020). Applications and datasets for superpixel techniques: A survey. *Journal of Computer Science and Information Systems*, 15(3), 1-6.
- [9] Ghoneim, S. S., Farrag, T. A., Rashed, A. A., El-Kenawy, E. S. M., & Ibrahim, A. (2021). Adaptive dynamic meta-heuristics for feature selection and classification in diagnostic accuracy of transformer faults. *IEEE Access*, 9, 78324-78340.
- [10] El-kenawy, E. S. M., Eid, M. M., & Ibrahim, A. (2021). Anemia estimation for covid-19 patients using a machine learning model. *Journal of Computer Science and Information Systems*, 17(11), 2535-1451.
- [11] Eid, M. M., & El-Sayed, M. El-kenawy, and Abdelhameed Ibrahim." An Advanced Patient Health Monitoring System.". *Journal of Computer Science and Information Systems*, 17.
- [12] El-Kenawy, E. S. M., Mirjalili, S., Ghoneim, S. S., Eid, M. M., El-Said, M., Khan, Z. S., & Ibrahim, A. (2021). Advanced Ensemble Model for Solar Radiation Forecasting Using Sine Cosine Algorithm and Newton's Laws. *IEEE Access*, 9, 115750-115765.
- [13] El-kenawy, E. S. M., Eid, M. M., & Ibrahim, A. (2021). Automatic identification from noisy microscopic images. *Journal of Computer Science and Information Systems*, 17(11).
- [14] Salamai, A. A., El-kenawy, E. S. M., & Abdelhameed, I. (2021). Dynamic Voting Classifier for Risk Identification in Supply Chain 4.0. *CMC-COMPUTERS MATERIALS & CONTINUA*, 69(3), 3749-3766.
- [15] Alharbi, M. S., & El-kenawy, E. S. M. (2021). Optimize Machine Learning Programming Algorithms for Sentiment Analysis in Social Media. *International Journal of Computer Applications*, 174(25), 38-43.
- [16] Alharbi, M. S., & El-kenawy, E. S. M. (2021). Recommendation System for Analyzing the Preference Data of the Multimedia Software Tools in Education.
- [17] Eid, M. M., El-kenawy, E. S. M., & Ibrahim, A. (2021, March). A binary sine cosine-modified whale optimization algorithm for feature selection. In *2021 National Computing Colleges Conference (NCCC)* (pp. 1-6). IEEE.
- [18] Ibrahim, A., Mirjalili, S., El-Said, M., Ghoneim, S. S., Al-Harhi, M. M., Ibrahim, T. F., & El-Kenawy, E. S. M. (2021). Wind Speed Ensemble Forecasting Based on Deep Learning Using Adaptive Dynamic Optimization Algorithm. *IEEE Access*, 9, 125787-125804.
- [19] Eid, M. M., & El-Sayed, M. El-kenawy, and Abdelhameed Ibrahim." A Fast Real-Time Video Encryption/Decryption Technique Based on Hybrid Chaotic Maps.". *Journal of Computer Science and Information Systems*, 18.
- [20] Eid, M. M., & El-Sayed, M. El-kenawy, and Abdelhameed Ibrahim.". A New Hybrid Video Encryption Technique Based on Chaos Cryptography.
- [21] E. -S. M. El-Kenawy et al., "Novel Meta-Heuristic Algorithm for Feature Selection, Unconstrained Functions and Engineering Problems," in *IEEE Access*, vol. 10, pp. 40536-40555, 2022, doi: 10.1109/ACCESS.2022.3166901.
- [22] A. E. Takieldeem, E. M. El-kenawy, M. Hadwan and R. M. Zaki, "Dipper throated optimization algorithm for unconstrained function and feature selection," *Computers, Materials & Continua*, vol. 72, no.1, pp. 1465-1481, 2022.
- [23] E. M. El-kenawy, A. Ibrahim, S. Mirjalili, Y. Zhang, S. Elnazer *et al.*, "Optimized ensemble algorithm for predicting metamaterial antenna parameters," *Computers, Materials & Continua*, vol. 71, no.3, pp. 4989-5003, 2022.

- [24] E. M. El-Kenawy, A. Ibrahim, N. Bailek, K. Bouchouicha, M. A. Hassan *et al.*, "Hybrid ensemble-learning approach for renewable energy resources evaluation in algeria," *Computers, Materials & Continua*, vol. 71, no.3, pp. 5837–5854, 2022.
- [25] A. A. Salamai, A. A. Ageeli and E. M. El-kenawy, "Forecasting e-commerce adoption based on bidirectional recurrent neural networks," *Computers, Materials & Continua*, vol. 70, no.3, pp. 5091–5106, 2022.
- [26] E.-S. M. El-kenawy, A. Ibrahim, N. Bailek, K. Bouchouicha, M. A. Hassan *et al.*, "Sunshine duration measurements and predictions in Saharan Algeria region: An improved ensemble learning approach," *Theoretical and Applied Climatology*, vol. 2021, pp. 1-17, 2021.
- [27] Nijhawan, R., Kumar, M., Arya, S., Mendiritta, N., Kumar, S., Towfek, S. K., ... & Abdelhamid, A. A. (2023). A Novel Artificial-Intelligence-Based Approach for Classification of Parkinson's Disease Using Complex and Large Vocal Features. *Biomimetics*, 8(4), 351.
- [28] Khafaga, D. S., El-kenawy, E. S. M., Alhussan, A. A., & Eid, M. M. (2023). Forecasting Energy Consumption Using a Novel Hybrid Dipper Throated Optimization and Stochastic Fractal Search Algorithm. *Intelligent Automation & Soft Computing*, 37(2).
- [29] Shams, M. Y., El-kenawy, E. S. M., Ibrahim, A., & Elshewey, A. M. (2023). A hybrid dipper throated optimization algorithm and particle swarm optimization (DTPSO) model for hepatocellular carcinoma (HCC) prediction. *Biomedical Signal Processing and Control*, 85, 104908.
- [30] Abdelhamid, A. A., El-kenawy, E. S. M., Ibrahim, A., Eid, M. M., Khafaga, D. S., Alhussan, A. A., ... & Shams, M. Y. (2023). Innovative Feature Selection Method Based on Hybrid Sine Cosine and Dipper Throated Optimization Algorithms. *IEEE Access*.
- [31] Karim, F. K., Khafaga, D. S., Eid, M. M., Towfek, S. K., & Alkahtani, H. K. (2023). A Novel Bio-Inspired Optimization Algorithm Design for Wind Power Engineering Applications Time-Series Forecasting. *Biomimetics*, 8(3), 321.
- [32] Alhasani, A. T., Alkattan, H., Subhi, A. A., El-Kenawy, E. S. M., & Eid, M. M. A Comparative Analysis of Methods for Detecting and Diagnosing Breast Cancer Based on Data Mining. *Methods*, 7, 9.
- [33] Alakkari, K., Subhi, A. A., Alkattan, H., Kadi, A., Malinin, A., Potoroko, I., ... & El-kenawy, E. S. M. (2023). Forecasting COVID-19 Infection Using Encoder-Decoder LSTM and Attention LSTM Algorithms. *Journal of Intelligent Systems & Internet of Things*, 8(2).
- [34] El-kenawy, E. S. M., Abdelhamid, A. A., Alrowais, F., Abotaleb, M., Ibrahim, A., & Khafaga, D. S. (2023). Al-Biruni Based Optimization of Rainfall Forecasting in Ethiopia. *Computer Systems Science & Engineering*, 46(1).
- [35] Alhussan, A. A., Abdelhamid, A. A., Towfek, S. K., Ibrahim, A., Abualigah, L., Khodadadi, N., ... & Ahmed, A. E. (2023). Classification of Breast Cancer Using Transfer Learning and Advanced Al-Biruni Earth Radius Optimization. *Biomimetics*, 8(3), 270.
- [36] Alhussan, A. A., Farhan, A. K., Abdelhamid, A. A., El-Kenawy, E. S. M., Ibrahim, A., & Khafaga, D. S. (2023). Optimized ensemble model for wind power forecasting using hybrid whale and dipper-throated optimization algorithms. *Frontiers in Energy Research*, 11, 1174910.
- [37] Alhussan, A. A., Abdelhamid, A. A., Towfek, S. K., Ibrahim, A., Eid, M. M., Khafaga, D. S., & Saraya, M. S. (2023). Classification of Diabetes Using Feature Selection and Hybrid Al-Biruni Earth Radius and Dipper Throated Optimization. *Diagnostics*, 13(12), 2038.
- [38] Alharbi, A. H., Abdelhamid, A. A., Ibrahim, A., Towfek, S. K., Khodadadi, N., Abualigah, L., ... & Ahmed, A. E. (2023). Improved Dipper-Throated Optimization for Forecasting Metamaterial Design Bandwidth for Engineering Applications. *Biomimetics*, 8(2), 241.
- [39] Alharbi, A. H., Towfek, S. K., Abdelhamid, A. A., Ibrahim, A., Eid, M. M., Khafaga, D. S., ... & Saber, M. (2023). Diagnosis of Monkeypox Disease Using Transfer Learning and Binary Advanced Dipper Throated Optimization Algorithm. *Biomimetics*, 8(3), 313.
- [40] Abdelhamid, A. A., Towfek, S. K., Khodadadi, N., Alhussan, A. A., Khafaga, D. S., Eid, M. M., & Ibrahim, A. (2023). Waterwheel Plant Algorithm: A Novel Metaheuristic Optimization Method. *Processes*, 11(5), 1502.
- [41] Alhussan, A. A., M El-Kenawy, E. S., Abdelhamid, A. A., Ibrahim, A., Eid, M. M., & Khafaga, D. S. (2023). Wind speed forecasting using optimized bidirectional LSTM based on dipper throated and genetic optimization algorithms. *Frontiers in Energy Research*, 11, 1172176.
- [42] Khafaga, D. S., Alhussan, A. A., Abdelhamid, A. A., Ibrahim, A., Saber, M., & El-kenawy, E. S. M. (2023). Dipper Throated Algorithm for Feature Selection and Classification in Electrocardiogram. *Computer Systems Science & Engineering*, 45(2).
- [43] Alhussan, A. A., Eid, M. M., Towfek, S. K., & Khafaga, D. S. (2023). Breast Cancer Classification Depends on the Dynamic Dipper Throated Optimization Algorithm. *Biomimetics*, 8(2), 163.
- [44] Aqdu, A., Amin, R., Ramzan, S., Alshamrani, S. S., Alshehri, A., & El-kenawy, E. S. M. (2023). Detection Collision Flows in SDN Based 5G Using Machine Learning Algorithms. *Computers, Materials & Continua*, 75(1).
- [45] Ramadass, R., Venumula, S., Shankar, T. S., & Syed, K. (2023). Application Reliable Traffic Control Method for Efficient Data Management in Wireless-aided Computer Applications. *IJRJET*, 8(3).
- [46] Alqahtani, F., Abotaleb, M., Subhi, A. A., El-Kenawy, E. S. M., Abdelhamid, A. A., Alakkari, K., ... & Kadi, A. (2023). A hybrid deep learning model for rainfall in the wetlands of southern Iraq. *Modeling Earth Systems and Environment*, 1-18.
- [47] Myriam, H., Abdelhamid, A. A., El-Kenawy, E. S. M., Ibrahim, A., Eid, M. M., Jamjoom, M. M., & Khafaga, D. S. (2023). Advanced meta-heuristic algorithm based on Particle Swarm and Al-biruni Earth Radius optimization methods for oral cancer detection. *IEEE Access*, 11, 23681-23700.
- [48] El-Kenawy, E. S. M., Mirjalili, S., Khodadadi, N., Abdelhamid, A. A., Eid, M. M., El-Said, M., & Ibrahim, A. (2023). Feature selection in wind speed forecasting systems based on meta-heuristic optimization. *Plos one*, 18(2), e0278491.
- [49] Abdelhamid, A. A., El-Kenawy, E. S. M., Khodadadi, N., Mirjalili, S., Khafaga, D. S., Alharbi, A. H., ... & Saber, M. (2022). Classification of monkeypox images based on transfer learning and the Al-Biruni Earth Radius Optimization algorithm. *Mathematics*, 10(19), 3614.
- [50] El-Kenawy, E. S. M., Mirjalili, S., Abdelhamid, A. A., Ibrahim, A., Khodadadi, N., & Eid, M. M. (2022). Meta-heuristic optimization and keystroke dynamics for authentication of smartphone users. *Mathematics*, 10(16), 2912.
- [51] El-kenawy, E. S. M., Albalawi, F., Ward, S. A., Ghoneim, S. S., Eid, M. M., Abdelhamid, A. A., ... & Ibrahim, A. (2022). Feature selection and classification of transformer faults based on novel meta-heuristic algorithm. *Mathematics*, 10(17), 3144.
- [52] Atteia, G., Abdel Samee, N., El-Kenawy, E. S. M., & Ibrahim, A. (2022). CNN-Hyperparameter Optimization for Diabetic Maculopathy Diagnosis in Optical Coherence Tomography and Fundus Retinography. *Mathematics*, 10(18), 3274.
- [53] Abdelhamid, A. A., El-Kenawy, E. S. M., Khodadadi, N., Mirjalili, S., Khafaga, D. S., Alharbi, A. H., ... & Saber, M. (2022). Classification of monkeypox images based on transfer learning and the Al-Biruni Earth Radius Optimization algorithm. *Mathematics*, 10(19), 3614.

- [54] Khodadadi, N., Abualigah, L., El-Kenawy, E. S. M., Snaes, V., & Mirjalili, S. (2022). An archive-based multi-objective arithmetic optimization algorithm for solving industrial engineering problems. *IEEE Access*, *10*, 106673-106698.
- [55] Eid, M. M., El-Kenawy, E. S. M., Khodadadi, N., Mirjalili, S., Khodadadi, E., Abotaleb, M., ... & Khafaga, D. S. (2022). Meta-heuristic optimization of LSTM-based deep network for boosting the prediction of monkeypox cases. *Mathematics*, *10*(20), 3845.
- [56] El-Kenawy, E. S. M., Khodadadi, N., Khoshnaw, A., Mirjalili, S., Alhussan, A. A., Khafaga, D. S., ... & Abdelhamid, A. A. (2022). Advanced dipper-throated meta-heuristic optimization algorithm for digital image watermarking. *Applied Sciences*, *12*(20), 10642.
- [57] Alsayadi, H. A., Abdelhamid, A. A., El-Kenawy, E. S. M., Ibrahim, A., & Eid, M. M. (2022). Ensemble of Machine Learning Fusion Models for Breast Cancer Detection Based on the Regression Model. *Fusion: Practice & Applications*, *9*(2).
- [58] Djaafari, A., Ibrahim, A., Bailek, N., Bouchouicha, K., Hassan, M. A., Kuriqi, A., ... & El-Kenawy, E. S. M. (2022). Hourly predictions of direct normal irradiation using an innovative hybrid LSTM model for concentrating solar power projects in hyper-arid regions. *Energy Reports*, *8*, 15548-15562.
- [59] Ang, K. M., El-kenawy, E. S. M., Abdelhamid, A. A., Ibrahim, A., Alharbi, A. H., Khafaga, D. S., ... & Lim, W. H. (2022). Optimal Design of Convolutional Neural Network Architectures Using Teaching-Learning-Based Optimization for Image Classification. *Symmetry*, *14*(11), 2323.
- [60] Ali, R. S., Akif, O. Z., Jassim, S. A., Farhan, A. K., El-Kenawy, E. S. M., Ibrahim, A., ... & Abdelhamid, A. A. (2022). Enhancement of the CAST Block Algorithm Based on Novel S-Box for Image Encryption. *Sensors*, *22*(21), 8527.
- [61] Khafaga, D. S., Ibrahim, A., El-Kenawy, E. S. M., Abdelhamid, A. A., Karim, F. K., Mirjalili, S., ... & Ghoneim, M. E. (2022). An Al-Biruni earth radius optimization-based deep convolutional neural network for classifying monkeypox disease. *Diagnostics*, *12*(11), 2892.
- [62] El-Kenawy, E. S. M., Khodadadi, N., Mirjalili, S., Makarovskikh, T., Abotaleb, M., Karim, F. K., ... & Khafaga, D. S. (2022). Metaheuristic optimization for improving weed detection in wheat images captured by drones. *Mathematics*, *10*(23), 4421.
- [63] Abdelhamid, A. A., El-Kenawy, E. S. M., Alrowais, F., Ibrahim, A., Khodadadi, N., Lim, W. H., ... & Khafaga, D. S. (2022). Deep learning with dipper throated optimization algorithm for energy consumption forecasting in smart households. *Energies*, *15*(23), 9125.
- [64] Ang, K. M., Chow, C. E., El-Kenawy, E. S. M., Abdelhamid, A. A., Ibrahim, A., Karim, F. K., ... & Lim, W. H. (2022). A Modified Particle Swarm Optimization Algorithm for Optimizing Artificial Neural Network in Classification Tasks. *Processes*, *10*(12), 2579.
- [65] Potoroko, I., Kadi, A., Paymulina, A., Bagale, U., Abotaleb, M., & El-Kenawy, E. M. (2022, December). Food resources in food system technology: Bifunctional food system technology based on pickering emulsions. In *6th Smart Cities Symposium (SCS 2022)* (Vol. 2022, pp. 368-371). IET.
- [66] Matuka, A., Asafo, S. S., Eweke, G. O., Mishra, P., Ray, S., Abotaleb, M., ... & Chowdhury, S. (2022, December). Analysing the impact of COVID-19 outbreak and economic policy uncertainty on stock markets in major affected economies. In *6th Smart Cities Symposium (SCS 2022)* (Vol. 2022, pp. 372-378). IET.
- [67] Jamei, M., Bailek, N., Bouchouicha, K., Hassan, M. A., Elbeltagi, A., Kuriqi, A., ... & El-kenawy, E. S. M. (2023). Data-Driven Models for Predicting Solar Radiation in Semi-Arid Regions. *Computers, Materials & Continua*, *74*(1), 1625-1640.
- [68] Alkanhel, R., Khafaga, D. S., El-kenawy, E. S. M., Abdelhamid, A. A., Ibrahim, A., Amin, R., ... & El-den, B. M. (2023). Hybrid Grey Wolf and Dipper Throated Optimization in Network Intrusion Detection Systems. *CMC-COMPUTERS MATERIALS & CONTINUA*, *74*(2), 2695-2709.
- [69] Khafaga, D. S., El-kenawy, E. S. M., Karim, F. K., Abotaleb, M., Ibrahim, A., Abdelhamid, A. A., & Elsheweikh, D. L. (2023). Hybrid Dipper Throated and Grey Wolf Optimization for Feature Selection Applied to Life Benchmark Datasets. *CMC-COMPUTERS MATERIALS & CONTINUA*, *74*(2), 4531-4545.
- [70] El-kenawy, E. S. M., Abdelhamid, A. A., Ibrahim, A., Mirjalili, S., Khodadadi, N., Al Duailij, M. A., ... & Khafaga, D. S. (2023). Al-Biruni Earth Radius (BER) metaheuristic search optimization algorithm. *Comput. Syst. Sci. Eng.*, *45*(2), 1917-1934.
- [71] Khafaga, D. S., Karim, F. K., Abdelhamid, A. A., El-kenawy, E. S. M., Alkahtani, H. K., Khodadadi, N., ... & Ibrahim, A. (2023). Voting Classifier and Metaheuristic Optimization for Network Intrusion Detection. *CMC-COMPUTERS MATERIALS & CONTINUA*, *74*(2), 3183-3198.
- [72] Saber, M., El-Kenawy, E. S. M., Ibrahim, A., & Eid, M. M. (2023). Watermarking System for Medical Images Using Optimization Algorithm. *Fusion: Practice & Applications*, *10*(1).
- [73] Ibrahim A, El-kenawy E-SM, Kabeel AE, Karim FK, Eid MM, Abdelhamid AA, Ward SA, El-Said EMS, El-Said M, Khafaga DS. Al-Biruni Earth Radius Optimization Based Algorithm for Improving Prediction of Hybrid Solar Desalination System. *Energies*. 2023; *16*(3):1185. <https://doi.org/10.3390/en16031185>
- [74] Alkanhel, R., El-kenawy, E. S. M., Elsheweikh, D. L., Abdelhamid, A. A., Ibrahim, A., & Khafaga, D. S. (2023). Metaheuristic Optimization of Time Series Models for Predicting Networks Traffic. *CMC-COMPUTERS MATERIALS & CONTINUA*, *75*(1), 427-442.
- [75] Atteia, G., El-kenawy, E. S. M., Samee, N. A., Jamjoom, M. M., Ibrahim, A., Abdelhamid, A. A., ... & Shams, M. Y. (2023). Adaptive dynamic dipper throated optimization for feature selection in medical data. *Computers, Materials & Continua*, *75*(1), 1883-1900.
- [76] Alhussan AA, El-Kenawy E-SM, Saeed MA, Ibrahim A, Abdelhamid AA, Eid MM, El-Said M, Khafaga DS, Abualigah L and Elbaksawi O (2023) Green hydrogen production ensemble forecasting based on hybrid dynamic optimization algorithm. *Front. Energy Res.* *11*:1221006. doi: 10.3389/fenrg.2023.1221006
- [77] Al-Nuaimi, B. T., Al-Mahdawi, H. K., Albadran, Z., Alkattan, H., Abotaleb, M., & El-kenawy, E. S. M. (2023). Solving of the inverse boundary value problem for the heat conduction equation in two intervals of time. *Algorithms*, *16*(1), 33.
- [78] Ibrahim, A., El-kenawy, E. S. M., Kabeel, A. E., Karim, F. K., Eid, M. M., Abdelhamid, A. A., ... & Khafaga, D. S. (2023). Al-Biruni Earth Radius Optimization Based Algorithm for Improving Prediction of Hybrid Solar Desalination System. *Energies*, *16*(3), 1185.
- [79] Alghamdi, A. A., Ibrahim, A., El-Kenawy, E. S. M., & Abdelhamid, A. A. (2023). Renewable Energy Forecasting Based on Stacking Ensemble Model and Al-Biruni Earth Radius Optimization Algorithm. *Energies*, *16*(3), 1370.
- [80] Alkanhel, R., El-kenawy, E. S. M., Abdelhamid, A. A., Ibrahim, A., Alohal, M. A., Abotaleb, M., & Khafaga, D. S. (2023). Network Intrusion Detection Based on Feature Selection and Hybrid Metaheuristic Optimization. *Computers, Materials & Continua*, *74*(2).

- [81] Khafaga, D. S., El-kenawy, E. S. M., Alrowais, F., Kumar, S., Ibrahim, A., & Abdelhamid, A. A. (2023). Novel Optimized Feature Selection Using Metaheuristics Applied to Physical Benchmark Datasets. *Computers, Materials & Continua*, 74(2).
- [82] Khafaga, D. S., El-kenawy, E. S. M., Karim, F. K., Alshetwi, S., Ibrahim, A., Abdelhamid, A. A., & Elsheweikh, D. L. (2023). Optimization of Electrocardiogram Classification Using Dipper Throated Algorithm and Differential Evolution. *Computers, Materials & Continua*, 74(2).
- [83] Mohamed Saber, El-Sayed M. El-Kenawy, Abdelhameed Ibrahim, Marwa M. Eid, Abdelaziz A. Abdelhamid. (2022). New Optimization Models for Sine Cosine Functions in Embedded Telecommunication Systems. *International Journal of Wireless and Ad Hoc Communication*, 3 (2), 102-109.
- [84] Mohamed Saber, El-Sayed M. El-Kenawy, Abdelhameed Ibrahim, Marwa M. Eid, Abdelaziz A. Abdelhamid. (2023). Metaheuristic Optimized Ensemble Model for Classification of SMS Spam in Computer Networks. *International Journal of Wireless and Ad Hoc Communication*, 6 (2), 56-64.
- [85] Marwa M. Eid, El-Sayed M. El-Kenawy, Abdelhameed Ibrahim, Abdelaziz A. Abdelhamid, Mohamed Saber. (2022). Bank Marketing Data Classification Using Optimized Voting Ensemble, Sine Cosine, and Genetic Algorithms. *American Journal of Business and Operations Research*, 8 (2), 16-24.
- [86] A. A. Alhussan *et al.*, "A Binary Waterwheel Plant Optimization Algorithm for Feature Selection," in *IEEE Access*, doi: 10.1109/ACCESS.2023.3312022.
- [87] El-Sayed M. El-Kenawy, Abdelhameed Ibrahim, Abdelaziz A. Abdelhamid, Mohamed Saber, Marwa M. Eid. (2022). Metaheuristic Optimized Voting Ensemble for Recognizing Daily and Sports Activities. *Journal of Artificial Intelligence and Metaheuristics*, 2 (2), 08-17.
- [88] S. K. Towfek. (2023). Navigating the Storm: Cutting-Edge Risk Mitigation and Analysis for Volatile Markets. *Journal of Artificial Intelligence and Metaheuristics*, 4 (2), 36-44.
- [89] S. K. Towfek. (2023). A Semantic Approach for Extracting the Medical Association Rules. *Journal of Artificial Intelligence and Metaheuristics*, 5 (1), 46-52.
- [90] El-Kenawy, E. S., & Eid, M. (2020). Hybrid gray wolf and particle swarm optimization for feature selection. *Int. J. Innov. Comput. Inf. Control*, 16(3), 831-844.
- [91] El-kenawy, E. S. M. T. (2018). Solar radiation machine learning production depend on training neural networks with ant colony optimization algorithms. *International Journal of Advanced Research in Computer and Communication Engineering (IJARCCE)*, 7(5), 1-4.
- [92] El-kenawy, E. S. M. T. (2019). A Machine Learning Model for Hemoglobin Estimation and Anemia Classification. *International Journal of Computer Science and Information Security (IJCSIS)*, 17(2).
- [93] El-kenawy, E. S. M. T. (2018). Trust Model for Dependable File Exchange in Cloud Computing. *International Journal of Computer Applications*, 975, 8887.
- [94] Doaa Sami Khafaga, Abdelhameed Ibrahim, S. K. Towfek, Nima Khodadadi. (2023). Data Mining Techniques in Predictive Medicine: An Application in hemodynamic prediction for abdominal aortic aneurysm disease. *Journal of Artificial Intelligence and Metaheuristics*, 5 (1), 29-37.
- [95] Abdelaziz A. Abdelhamid, Marwa M. Eid, Mostafa Abotaleb, S. K. Towfek. (2023). Identification of Cardiovascular Disease Risk Factors Among Diabetes Patients using ontological Data Mining Techniques. *Journal of Artificial Intelligence and Metaheuristics*, 4 (2), 45-53.
- [96] S. K. Towfek, Nima Khodadadi. (2023). Deep Convolutional Neural Network and Metaheuristic Optimization for Disease Detection in Plant Leaves. *Journal of Intelligent Systems and Internet of Things*, 10 (1), 66-75
- [97] Ehsaneh Khodadadi, S. K. Towfek. (2023). Internet of Things Enabled Disease Outbreak Detection: A Predictive Modeling System. *Journal of Intelligent Systems and Internet of Things*, 10 (1), 84-91.
- [98] Ehsan khodadadi, S. K. Towfek ,Hussein Alkattan. (2023). Brain Tumor Classification Using Convolutional Neural Network and Feature Extraction. *Fusion: Practice and Applications*, 13 (2), 34-41
- [99] Khodadadi, N., Khodadadi, E., Al-Tashi, Q., El-Kenawy, E. S. M., Abualigah, L., Abdulkadir, S. J., ... & Mirjalili, S. (2023). BAOA: binary arithmetic optimization algorithm with K-nearest neighbor classifier for feature selection. *IEEE Access*.
- [100] Mijwil, M., Al-Mistarehi, A. H., Abotaleb, M., El-kenawy, E. S. M., Ibrahim, A., Abdelhamid, A. A., & Eid, M. M. (2023). From Pixels to Diagnoses: Deep Learning's Impact on Medical Image Processing-A Survey. *Wasit Journal of Computer and Mathematics Science*, 2(3), 8-14.
- [101] Ang, K. M., Lim, W. H., Tiang, S. S., Sharma, A., Towfek, S. K., Abdelhamid, A. A., ... & Khafaga, D. S. (2023). MTLBORKS-CNN: An Innovative Approach for Automated Convolutional Neural Network Design for Image Classification. *Mathematics*, 11(19), 4115.
- [102] Saber, M., & Eid, M. M. (2021). Low power pseudo-random number generator based on lemniscate chaotic map. *International Journal of Electrical and Computer Engineering*, 11(1), 863.
- [103] Saber, M. (2020). A novel design and Implementation of FBMC transceiver for low power applications. *Indonesian Journal of Electrical Engineering and Informatics (IJEI)*, 8(1), 83-93.
- [104] Jitsumatsu, Y., & Kohda, T. (2009, October). A low-power implementation of arctangent function for communication applications using FPGA. In *2009 Fourth International Workshop on Signal Design and its Applications in Communications* (pp. 60-63). IEEE.
- [105] Saber, M. (2017). Efficient Phase Recovery System. *Indonesian Journal of Electrical Engineering and Computer Science (IJECS)*, 5(1), 123-129. Saber, M., Jitsumatsu, Y., & Khan, M. T. A. (2012). A simple design to mitigate problems of conventional digital phase locked loop. *Signal Processing: An international journal (SPIJ)*, 6(2), 65-77.
- [106] Saber, M., Jitsumatsu, Y., & Khan, M. T. A. (2010, October). Design and implementation of low power digital phase-locked loop. In *2010 International Symposium On Information Theory & Its Applications* (pp. 928-933). IEEE.
- [107] Ali, N. S., & Divya, G. (2020). Prediction of Diseases in Smart Health Care System using Machine Learning. *International Journal of Recent Technology and Engineering*, 8(5), 2534-2537.
- [108] Eid, M. M., Alassery, F., Ibrahim, A., & Saber, M. (2022). Metaheuristic optimization algorithm for signals classification of electroencephalography channels. *Computers, Materials & Continua*, 71(3), 4627-4641.

- [109]Saber, M. (2022). Removing Powerline Interference from EEG Signal using Optimized FIR Filters. *J. Artif. Intell. Metaheuristics*, 1(1), 8-19.
- [110]Saber, M., & Abotaleb, M. (2022). Arrhythmia Modern Classification Techniques: A Review. *J. Artif. Intell. Metaheuristics*, 1, 42-53.
- [111]Mohamed Saber,Nader Behdad,Ehsaneh khodadadi. (2023). Detection of Breast Cancer Based on Feature Extraction Using WPSO in Conjunction with CNN. *Journal of Artificial Intelligence and Metaheuristics*, 5 (1), 16-28.
- [112]Nader Behdad,Mohamed Saber. (2023). PAPR Reduction in OFDM System Using Metaheuristic Algorithm. *Journal of Artificial Intelligence and Metaheuristics*, 4 (2), 28-35.
- [113]Pushan K. Dutta,David Winters,Nader Behdad,Mohamed Saber. (2022). Design and Implementation of Demodulator and Carrier Phase Compensation System for Satellite Communication. *International Journal of Wireless and Ad Hoc Communication*, 5 (1), 44-53.
- [114]Mohamed Saber,Pushan K. Dutta. (2022). Uniform and Nonuniform Filter Banks Design Based on Fusion Optimization. *Fusion: Practice and Applications*, 9 (1), 29-37.
- [115]El-kenawy, E. S. M., Khodadadi, N., Mirjalili, S., Abdelhamid, A. A., Eid, M. M., & Ibrahim, A. (2024). Greylag Goose Optimization: Nature-inspired optimization algorithm. *Expert Systems with Applications*, 238, 122147.
- [116]A. Ibrahim et al., "A Recommendation System for Electric Vehicles Users Based on Restricted Boltzmann Machine and WaterWheel Plant Algorithms," in *IEEE Access*, doi: 10.1109/ACCESS.2023.3345342.
- [117]Upadhyay, P., Marriboina, V., Goyal, S. J., Kumar, S., El-Kenawy, E. S. M., Ibrahim, A., ... & Khafaga, D. S. (2023). An improved deep reinforcement learning routing technique for collision-free VANET. *Scientific Reports*, 13(1), 21796.
- [118]Abdullah, S. M., Periyasamy, M., Kamaludeen, N. A., Towfek, S. K., Marappan, R., Kidambi Raju, S., ... & Khafaga, D. S. (2023). Optimizing Traffic Flow in Smart Cities: Soft GRU-Based Recurrent Neural Networks for Enhanced Congestion Prediction Using Deep Learning. *Sustainability*, 15(7), 5949.
- [119]Alhussan, A. A., M El-Kenawy, E. S., Abdelhamid, A. A., Ibrahim, A., Eid, M. M., & Khafaga, D. S. (2023). Wind speed forecasting using optimized bidirectional LSTM based on dipper throated and genetic optimization algorithms. *Frontiers in Energy Research*, 11, 1172176.
- [120]B. Sameh et al., "IoT-Based System for Crop Forecasting: Design and Implementation," 2023 3rd International Conference on Electronic Engineering (ICEEM), Menouf, Egypt, 2023, pp. 1-7, doi: 10.1109/ICEEM58740.2023.10319527.
- [121]K. Sherif, M. Azmy, K. Alakkari, M. Abotaleb and E. -S. M. El-Kenawy, "Deep Learning in IoT: An LSTM Approach for NDVI Forecasting," 2023 3rd International Conference on Electronic Engineering (ICEEM), Menouf, Egypt, 2023, pp. 1-7, doi: 10.1109/ICEEM58740.2023.10319616.
- [122]O. M. Osama, K. Alakkari, M. Abotaleb and E. -S. M. El-Kenawy, "Forecasting Global Monkeypox Infections Using LSTM: A Non-Stationary Time Series Analysis," 2023 3rd International Conference on Electronic Engineering (ICEEM), Menouf, Egypt, 2023, pp. 1-7, doi: 10.1109/ICEEM58740.2023.10319532.
- [123]M. Elshabrawy, M. M. Eid, A. A. Abdelhamid, E. -S. M. El-Kenawy and A. Ibrahim, "Forecasting of Monkeypox Cases Using Optimized SARIMAX Based Model," 2023 3rd International Conference on Electronic Engineering (ICEEM), Menouf, Egypt, 2023, pp. 1-6, doi: 10.1109/ICEEM58740.2023.10319521.
- [124]Sharma, A., Lim, W. H., El-Kenawy, E. S. M., Tiang, S. S., Bhandari, A. S., Alharbi, A. H., & Khafaga, D. S. (2023). Identification of photovoltaic module parameters by implementing a novel teaching learning based optimization with unique exemplar generation scheme (TLBO-UEGS). *Energy Reports*, 10, 1485-1506.
- [125]Catherine, A. T., Towfek, S. K., & Abdelhamid, A. A. (2023). An Overview of the Evolution and Impact of Chatbots in Modern Healthcare Services. *Mesopotamian Journal of Artificial Intelligence in Healthcare*, 2023, 71-75.
- [126]Ammar Kadi,Adel Oubelaid,S. K. Towfek. (2023). Electrocardiogram Comparison as a Biometric Identifier: A Review. *Journal of Artificial Intelligence and Metaheuristics*, 5 (2), 31-40.
- [127]S.K.Towfek. (2023). CNN-Based Multiclass Classification for COVID-19 in Chest X-ray Images. *Journal of Artificial Intelligence and Metaheuristics*, 6 (1), 48-55.
- [128]Ahmed Mohamed Zaki,S. K. Towfek,Weiguo Gee,Wang Zhang,Marwa Adel Soliman. (2023). Advancing Parking Space Surveillance using A Neural Network Approach with Feature Extraction and Dipper Throated Optimization Integration. *Journal of Artificial Intelligence and Metaheuristics*, 6 (2), 16-25.
- [129]Faris H. Rizk,Sofia Arkhstan,Ahmed Mohamed Zaki,Mohamed Ahmed Kandel,S. K. Towfek. (2023). Integrated CNN and Waterwheel Plant Algorithm for Enhanced Global Traffic Detection. *Journal of Artificial Intelligence and Metaheuristics*, 6 (2), 36-45.
- [130]Ahmed Mohamed Zaki,Nima Khodadadi,Wei Hong Lim,S. K. Towfek. (2024). Predictive Analytics and Machine Learning in Direct Marketing for Anticipating Bank Term Deposit Subscriptions. *American Journal of Business and Operations Research*, 11 (1), 79-88
- [131]Eman Shawky Mira,Ahmed M. Saaduddin Sapri ,Rowaa F. Aljehani,Bayan S. Jambi,Taseer Bashir,El-Sayed M. El-Kenawy,Mohamed Saber. (2024). Early Diagnosis of Oral Cancer Using Image Processing and Artificial Intelligence. *Fusion: Practice and Applications*, 14 (1), 293-308.

