A NEW HYBRID DEEP NEURAL NETWORKS (DNN) ALGORITHM FOR LORENZ CHAOTIC SYSTEM PARAMETER ESTIMATION IN IMAGE ENCRYPTION

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang Al-Sultan Abdullah or any other institutions.

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ABSTRAK

Fenomena kekacauan adalah antara salah satu penemuan yang baik sekitar abad ke-20 sehingga kini dan telah menjadikan bidang penyelidikan ini diminati para penyelidik. Sistem Lorenz ialah model matematik yang menggambarkan salah satu fenomena kekacauan. Ia adalah penyelesaian kepada satu set persamaan pembezaan yang dikenali sebagai Persamaan Lorenz, yang diperkenalkan oleh Edward N. Lorenz. Menghibridkan Rangkaian Neural Dalam (DNN) dengan algoritma Pengelompokan Purata-k akan meningkatkan ketepatan dan mengurangkan kerumitan pada data yang digunakan. Selain itu, parameter hiper DNN perlu ditala untuk mendapatkan tetapan yang optimum serta ia menjadi nilai penting bagi memastikan ketepatan model untuk mengkategorikan data yang digunakan. Tambahan pula, kaedah tradisional untuk aplikasi penyulitan imej seperti Piawaian Penyulitan Data (DES) tidak sesuai dengan data imej kerana ia memerlukan kapasiti yang besar apabila menglibatkan pemprosesan imej. Objektif pertama yang diterapkan dalam kajian ini ialah: untuk membangunkan algorithma Pembelajaran Dalam yang baru iaitu DNN dan Algoritma Pengelompokan Purata-K bagi menganggar sistem kekacauan Lorenz. Seterusnya, tujuan kajian ini ialah untuk mengoptimumkan parameter hiper DNN dengan menggunakan Algoritma Pengoptimuman Aritmetik (AOA) dan akhir sekali, untuk menilai kebolehan sistem yang telah dibangunkan dengan algoritma Simulasi Penapis Kalman (SKF) dalam menyelesaikan masalah penyulitan imej. Kajian ini menggunakan satu set data sebenar bagi sistem kekacauan Lorenz yang diolah oleh Profesor Roberto Barrio dari Universiti Zaragoza, Sepanyol. Set data yang digunakan telah dibahagikan kepada beberapa bahagian, iaitu set latihan, pengujian dan pengesahan sebanyak 70%, 15% dan 15%. Kajian ini dimulakan dengan pembangunkan model Pembelajaran Dalam secara hybrid yang terdiri daripada DNN dan Algoritma Pengelompokan Purata-K. Selepas itu, model yang telah dibangunkan itu akan digunakan untuk mengganggar parameter bagi system Lorenz. Tambahan pula, proses penalaan parameter hiper adalah penting untuk memastikan model yang dibina tepat dan cekap, akan di optimumkan oleh AOA. Akhir sekali, satu teknik gabungan dicadangkan untuk menangani masalah imej penyulitan dengan menggunakan sistem kekacauan Lorenz dan algoritma SKF. Untuk mendapatkan hasil yang optimum, penggunaan fungsi korelasi akan digunakan sebagai fungsi kecergasan untuk algoritma SKF ini. Seterusnya, hasil penemuan untuk kajian ini akan dianalisis dan dibincangkan. Bagi nilai ketepatan, model hybrid memperoleh 72.27% berbanding 66.47% untuk model kendiri. Selain itu, bagi nilai susut pula, model kendiri memperoleh 0.3661 iaitu lebih tinggi daripada model hibrid yang telah dibangunkan, 0.1712. Prestasi yang baik telah ditunjukkan oleh algoritma pengelompokan untuk meningkatkan ketepatan model. Daripada hasil dapatan penggabungkan dua objektif kajian mendapati nilai R^2 dan ρ lebih tinggi berbanding model kendiri iaitu 0.1964 dan 0.0045. Untuk nilai RMSE dan MAE bagi hibrid model pula, masing-masing ialah 0.2913 dan 0.1976. Secara keseluruhan, model hibrid menunjukkan prestasi yang lebih baik berbanding model kendiri berdasarkan dapatan daripada nilai-nilai metrik tersebut dan juga boleh meramalkan hasil parameter dengan tepat. Kajian ini juga membincangkan analisis secara terperinci bagi system penyulitan imej termasuk analisis statistik, keselamatan dan keteguhan. Satu perbandingan antara tujuh kaedah penyulitan imej yang berbeza juga dibincangkan di dalam tesis ini. Berdasarkan hasil dapatan untuk serangan pemotongan gambar, kaedah yang dicadangkan memperoleh nilai PSNR yang lebih baik untuk dua nisbah kehilangan piksel gambar iaitu 1/16 dan ¼. Zhou et al. memperoleh nilai PSNR yang lebih untuk nisbah ½ kehilangan piksel gambar sahaja.

ABSTRACT

One of the greatest discoveries of the 20th century was the chaotic phenomenon, which has been a popular area of study up to this point. The Lorenz Attractor is a mathematical model that describes a chaotic system. It is a solution to a set of differential equations known as the Lorenz Equations, which Edward N. Lorenz originally introduced. Hybridizing the Deep Neural Network (DNN) with the K-Means Clustering algorithm will increase the accuracy and reduce the data complexity of the Lorenz dataset. Then, hyperparameters of DNN must be tuned to get the best setting for a given problem, and it becomes crucial to evaluate them to verify whether the model can accurately categorize the data. Furthermore, conventional encryption methods such as Data Encryption Standards (DES) are not adapted to image data because of their high redundancy and big capacity. The first research objective is to develop a new deep learning algorithm by a hybrid of DNN and K-Means Clustering algorithms for estimating the Lorenz chaotic system. Then, this study aims to optimize the hyperparameters of the developed DNN model using the Arithmetic Optimization Algorithm (AOA) and, lastly, to evaluate the performance of the newly proposed deep learning model with Simulated Kalman Filter (SKF) algorithm in solving image encryption application. This work uses a Lorenz dataset from Professor Roberto Barrio of the University of Zaragoza in Spain and focuses on multi-class classification. The dataset was split into training, testing, and validation datasets, comprising 70%, 15%, and 15% of the total. The research starts with developing the hybrid deep learning model consisting of DNN and a K-Means Clustering Algorithm. Then, the developed algorithm is implemented to estimate the parameters of the Lorenz system. In addition, the hyperparameter tuning problem is considered in this research to improve the developed hybrid model by using the AOA algorithm. Lastly, a new hybrid technique suggests tackling the current image encryption application problem by using the estimated parameters of chaotic systems with an optimization algorithm, the SKF algorithm. The fitness function used is the correlation function in the SKF algorithm to optimize the cipher image produced using the Lorenz system. Next, the thesis will be discussed about the findings of this study. As for accuracy, the developed model obtained 72.27% compared to 66.47% for the baseline model. Besides, the baseline model's loss value is 0.3661, while the developed model is 0.1712, lower than the standalone model. Hence, the clustering algorithm is performed well to enhance the accuracy of the model performances, as mentioned in the first objective. The combination of the first two objectives obtained the R^2 value of 0.8054 and ρ value of 0.9912, which are higher than the standalone DNN model. Then, for the hybrid model, the Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE) values are 0.1964 and 0.0045, respectively. Both error values are lower than the baseline model, 0.2913 and 0.1976. The findings showed that the model improved the model's effectiveness and could predict the outcome accurately. This study also discusses the detailed analysis of the developed combined image encryption, including the statistical, security, and robustness analysis related to the third objective. The comparisons between seven image encryption schemes were discussed at the end of the subtopic. Based on the cropping attack's findings, the proposed technique obtained higher Peak Signal Noise Ratio (PSNR) values for two conditions, which are 1/16 and 1/4 cropping ratios. At the same time, Zhou et al. performed a higher PSNR value for a 1/2 cropping ratio only. In conclusion, hybrid DNN with the K-Means Clustering Algorithm is proven to resolve parameter estimations of the chaotic system by developing an accurate prediction model.

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