論 文 内 容 の 要 旨

The adaptive neuro-fuzzy inference system (ANFIS) is employed in a vast range of applications because of its smoothness (by Fuzzy Control (FC)) and adaptability (by Neural Network (NN)). Although ANFIS is better in non-linear optimization, two major loopholes must be addressed thoroughly. They are the curse of dimensionality and computational complexity. To overcome these complications, a novel usage of the ANFIS model is proposed as Cascaded-ANFIS. As the primary source of this algorithm, a general two-input one-output ANFIS algorithm is used. The novel algorithm has two main modules called pair selection and training model. Pair selection is responsible for selecting the best match for the inputs while the training module generates the output. The cascaded behaviour of the novel algorithm causes additional iterations to advance to the best solution. Even though the number of parameters that need to be adjusted is increasing at each additional iteration, the algorithm's complexity may stay stable.

The reliability and excellent performance of the Cascaded-ANFIS were tested by performing various experiments. Initially, two-hybrid state-of-the-art algorithms are used to compare the performance of the novel algorithm, namely, Particle Swarm Optimization based ANFIS (ANFIS-PSO) and Genetic Algorithm based ANFIS (ANFIS-GA). Furthermore, individual performance is presented for seven publicly recognized data sets. The results have demonstrated that, for some data sets, the Root means square error (RMSE) can be a minimum of 0.0001. Furthermore, the novel algorithm was used in several practical applications.
Automated fruit identification is always challenging due to its complex nature. Usually, the fruit types and sub-types are location-dependent; thus, manual fruit categorization is still a challenging problem. As the first application in real-time, the Cascaded-ANFIS was used on image classification tasks. Literature showcases several recent studies incorporating the Convolutional Neural Network-based algorithms (VGG16, Inception V3, MobileNet, and ResNet18) to classify the Fruit-360 dataset. However, none is comprehensive and has not been utilized for the total 131 fruit classes. In addition, the computational efficiency was not the best in these models.

A robust, comprehensive, novel study is done to identify and predict the entire Fruit-360 dataset, including 131 fruit classes with 90,483 sample images. An algorithm based on the Cascaded Adaptive Network-based Fuzzy Inference System (Cascaded-ANFIS) was effectively utilized to achieve the research gap. Colour Structure, Region Shape, Edge Histogram, Column Layout, Gray-Level Co-Occurrence Matrix, Scale-Invariant Feature Transform, Speeded Up Robust Features, Histogram of Oriented Gradients, and Oriented FAST and rotated BRIEF features are used in this study as the features descriptors in identifying fruit images. In this study, the algorithm was validated using two methods: iterations and confusion matrix.

The results show that the proposed method has a relative accuracy of 98.36%. The Fruit-360 dataset is unbalanced; therefore, the weighted precision, recall, and F1-Score were calculated as 0.9843, 0.9841, and 0.9840, respectively. In addition, the developed system was tested and compared against the literature-found state-of-the-art algorithms for the purpose. Comparison studies present the acceptability of the newly developed algorithm handling the whole Fruit-360 dataset and achieving high computational efficiency. Furthermore, the Cascaded-ANFIS was employed in several other real-world applications in different fields, such as hydropower prediction, flood prediction and

forecasting.

Hydropower is a crucial power source in the current world, and there is a vast range of benefits in forecasting power generation for the future. This study focuses on the significance of climate change on the future representation of the Samanalawewa Reservoir Hydropower Project in Sri Lanka using an architecture of the Cascaded ANFIS algorithm.

Moreover, the study assessed the capacity of the novel Cascaded ANFIS algorithm for handling regression problems and compared the results with the state-of-art regression models. The inputs to this system were the rainfall data of selected weather stations inside the catchment. The future rainfalls were generated using Global Climate Models at RCP4.5 and RCP8.5 and corrected for their biases. The Cascaded ANFIS algorithm was selected to handle this regression problem by comparing the best algorithm among the state-of-the-art regression models, such as RNN, LSTM, and GRU. The Cascaded ANFIS could forecast the power generation with a minimum error of 1.01, whereas the second-best algorithm, GRU, scored a 6.5 error rate. The predictions were carried out for the near future and mid-future and compared against the previous work. The results show that the algorithm can predict the variation of power generation with rainfall with a slight error rate. It was found that the research can be utilized in numerous areas for hydropower development.

The Rainfall-Runoff (R-R) relationship is essential to the hydrological cycle. Sophisticated hydrological models can accurately investigate R-R relationships; however, they require many data. Therefore, machine learning and soft computing techniques have taken the attention in the environment of limited hydrological, meteorological, and geological data. The accuracy of such models depends on the various parameters, including the quality of inputs and outputs and the used algorithms. However, identifying a perfect algorithm is still challenging. This study presents a method using Cascaded-ANFIS to predict runoff based on rainfall accurately. This study compared the model against three regression algorithms: Long Short-Term Memory, Grated Recurrent Unit, and Recurrent Neural Networks. These algorithms have been selected due to their outstanding performances in similar studies. The models were tested on the Mahaweli River, the longest in Sri Lanka. The results showcase that the Cascaded-ANFIS-based model outperforms the other algorithms. In addition, Shared Socio-economic Pathways (SSP2-4.5 and SSP5-8.5 scenarios) were used to generate future rainfalls, forecast the near-future and mid-future water levels, and identify potential flood events. The future forecasting results indicate a decrease in flood events and magnitudes in both SSP2-4.5 and SSP5-8.5 scenarios. Furthermore, the SSP5-8.5 scenario shows drought weather from May to August yearly. The results of this study can effectively be used to manage and control water resources and mitigate flood damages.

Hydrologic models require atmospheric, dynamic and static models to simulate river flow from catchments. Thus the accuracy of hydrologic modelling highly depends on the data quality. Therefore, simulation is always challenging in data-scarcity environments. In addition, physical flow measurements are infeasible in the Spatiotemporal domain, and soft computing techniques are helpful in river flow simulation in data-scarcity environments. This research proposes model implementation using the Cascaded-ANFIS algorithm to simulate river flows in the Spatiotemporal domain with limited input rainfall data. The developed generic rainfall-river flow model was applied to five river basins in different geographical and climatic areas and tested its accuracy against the measured river flows. Six statical metrics were used to evaluate the accuracy of the developed model. In addition, the proposed algorithm was tested against state-of-the-art machine learning algorithms such as Recurrent Neural Network, Linear Regression, Ridge Regression, Lasso Regression, Long Short-Term Memory, and Gated Recurrent Units. Excellent acceptability of simulated river flows against measured river flows can be presented irrespective of land use, geographic, and climatic regions.

Moreover, hydrologic models to simulate river flows are computationally costly. In addition to the precipitation time series and other meteorological time series, catchment characteristics, including soil data, land use and land cover, and roughness, are essential in most hydrologic models. The unavailability of these data series challenged the accuracy of simulations, thus impacting related designs. However, recent advances in soft computing techniques offer better approaches and solutions at less computational complexity. These require a minimum amount of data; however, they reach higher accuracies depending on the quality of data sets. The Gradient Boosting Algorithms and Adaptive Network-based Fuzzy Inference System are two such systems that can be used in simulating river flows based on the catchment rainfall. In this paper, the computational capabilities of these two systems were tested in simulated river flows by developing the prediction models for Malwathu Oya in Sri Lanka. The simulated flows were then compared with the ground-measured river flows for accuracy. Correlation of coefficient (R), Per cent-Bias (bias), Nash Sutcliffe Model efficiency coefficient (NSE), Mean Absolute Relative Error (MARE), Kling-Gupta Efficiency (KGE), and Root mean square error (RMSE) were used as the comparative indices between Gradient Boosting Algorithms and Adaptive Network-based Fuzzy Inference Systems. Results of the study showcased that both systems can simulate river flows as a function of catchment rainfalls; however, Cat gradient Boosting algorithm (CatBoost) has a computational edge over the Adaptive Network Based Fuzzy Inference System (ANFIS). The CatBoost algorithm outperformed other algorithms used in this study. However, more applications should be considered for sound conclusions. Therefore, as a conclusion of this dissertation thesis, it can be stated that the Cascaded-ANFIS has more outstanding capabilities and higher robustness than most of the traditional and black-box algorithms.