TELKOMNIKA Telecommunication, Computing, Electronics and Control
Vol. 18, No. 5, October 2020, pp. 2498~2504
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v18i5.14665

Prediction of rainfall using improved deep learning with particle swarm optimization

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Article Info

Article history:

Received Nov 24, 2019
Revised Apr 8, 2020
Accepted May 1, 2020

Keywords:

Deep PSO
Forecasting
Improved deep learning
Particle swarm optimization
Rainfall

ABSTRACT

Rainfall is a natural factor that is very important for farmers or certain institutions to predict the planting period of a plant. The problem is that rainfall is very difficult to predict. Trials to get optimal rainfall prediction have been carried out by BMKG through research with variety of methods in various fields, including meteorology, climatology and geophysics. The results of the study unfortunately obtained a less optimal success rate in predicting rainfall. Today, there are many new methods for predicting events. These methods include deep learning (DL) and Particle swarm optimization (PSO). The use of the deep learning method is very susceptible to initial weights that are less than optimal, so it requires a process of optimization using a metaheuristic technique, which is the PSO algorithm, because this algorithm has a level of complexity that is much lower than genetic algorithms. In this study, this method is utilized to predict rainfall by determining the exact regression equation model according to the number of layers in hidden nodes based on the size of the kernel and the weight between the layers. This research is approved achieved get more optimal rainfall prediction results that those of previous research that without optimization with PSO.

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1. INTRODUCTION

Malang Regency East Java Province is an area that has a quite high level of production in the Agriculture and Plantation sector [1]. The production will decrease if it harvest failures occur when entering the rainy season with high rainfall (above 300 mm per month) and when entering the dry season with low rainfall [2]. One of the efforts that have been made by farmers to overcome this problem is by harvesting early. These efforts are indeed effective enough to reduce the amount of loss. It would be better, however, to make a proactive effort to avoid crop failure [3].

The proactive efforts of the farmers to date are by examining the calendar to determine the best start of the growing season, like the one the Indonesian Agency for Agricultural Research and Development (Balitbangtan) of the Ministry of Agriculture does, which is twice a year. The planting period is determined by using '*dasarian'* (10 days) rainfall forecasting data to see the beginning of the entry and end of the rainy season or the dry season from the Meteorology, Climatology and Geophysical Agency/BMKG [4]. The problem is that this forecasting provided by BMKG is often inaccurate [5]; hence, the accuracy of the planting calendar from Balitbangtan has only reached 50% for the whole area of Indonesia [6].

To date, BMKG has often used adaptive neuro-fuzzy inference system (ANFIS) method [7], wavelet transformation [8] and autoregressive integrated moving average (ARIMA) [9], to predict rainfall. BMKG admitted that the accuracy of the method is still not good, which is 70%. Currently, there are many other methods used to forecast rainfall. One of the methods is deep learning (DL) which is contained in the neural network (NN). The drawback of this method is that it is often stuck at the local optimum because the initial weights are generated randomly. Therefore, it is necessary to have a technique that is able to accelerate the search for weights so that the results obtained can be optimal. Particle swarm optimization (PSO) algorithm in [10-18], is the algorithm that possesses same level of effectiveness with algorithm genetics in the completion of problems, but in terms of efficiency, PSO algorithm is superior to genetic algorithm [19]. Therefore, this research will apply the method of improved deep learning using PSO algorithm. It is expected that this method is able to predict rainfall in Malang Regency accurately.

2. RESEARCH METHOD

2.1. Rainfall

Rainfall is the height of rainwater that is collected on a flat place without experiencing evaporation, drainage or infiltration. One millimeter of rainfall means there is a water reservoir in a flat area as high as one millimeter or one liter [2, 20, 21]. Figure 1 displays the rainfall measured at various periods. The Meteorology Station will measure the rainfall in a short period of time (per hour and per day), while the Climatology Station will measure it in a long period of time (per 10 days and per month).

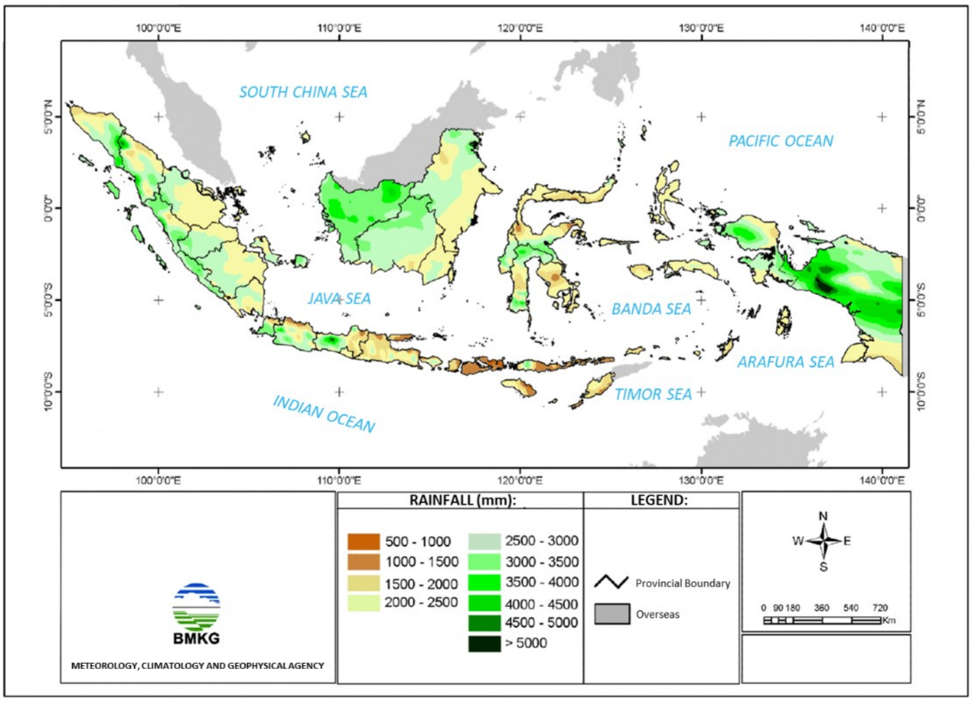

Figure 1. Map of rainfall in Indonesia [21]

2.2. Predictions and classifications

Prediction is a different thing from classification. The machine learning, however, considers classification as one kind of prediction. In the implementation of dataset preprosessing process, the classification uses the Technical Analysis and Fundamental Analysis approaches. The purpose of classification in this case is to predict the class or category labels [22-24]. The classification is divided into two types, which are:

a. Supervised classification (classification) and
b. Unsupervised classification (clustering)

The extraction results of initial data comes from, e.g. data 1 with 3 features (by technical analysis approach) that is displayed on Table 1 and the convertion result is placed in Table 2. Meanwhile, the illustration of the visualization form from Table 1 can be observed in Figure 2.

Table 1. Initial data (example create features using technical analysis)

No	X_1 (3 days ago	X_2 (2 days ago)	X_3 (1 day ago)	Y (target)
1	13338	13356	13332	13331
2	13356	13332	13331	..
..	13332	13331	..	..
..	13331	..	..	..
..	..	..	..	..
..	..	..	..	..

Table 2. The extraction results from initial data to image matrix

No	Image matrix: a square matrix with size [num_of_features x num_of_features]			Y (target)
1	13338	13356	13332	13331
	13338	13356	13332	
	13338	13356	13332	
..	..	..	..	..
..	..	..	..	..

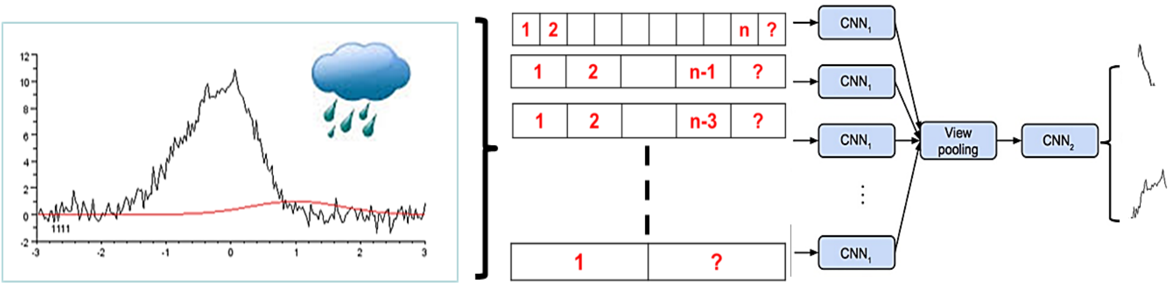

Figure 2. Design: 1D data (e.g. rainfall in mm-based time series)

2.3. Proposed method: improved deep learning with PSO

The deep learning algorithm with PSO can be utilized to predict rainfall in Malang Regency, where it works by changing the feature extraction and data transformation into image form. The amount of convolution and pooling layer depends on the complexity of the case. The convolution layer consists of several groups of features and the pooling layer consists of a reduction or summary of several groups of features [25-41]. Here are the detailed steps of deep learning with PSO:

a. Create a relevant map SDL-ELM with PSO based on Figure 3.
b. Set the parameter value.

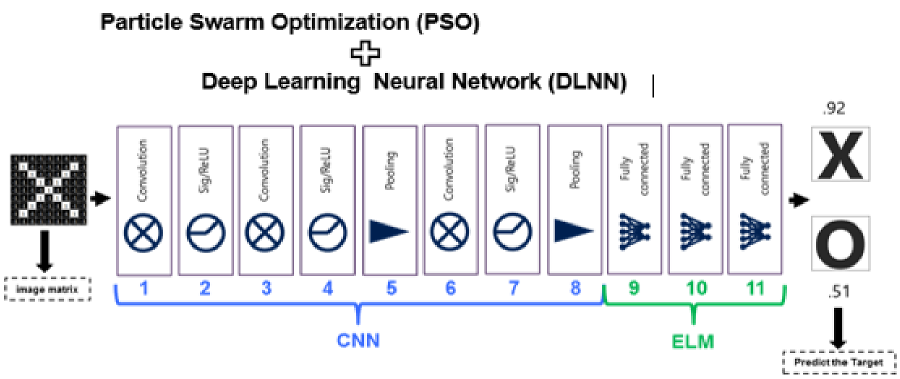

Figure 3. Map of simplified deep learning CNN based ELM with PSO (deep PSO)

c. Deep PSO process

This is the process where the representation of 4 dimensional clusters on each PSO particle in Hybrid PSO-DLNN (deep PSO) can be viewed in Table 3.

- Training process of SDLCNN-ELM
- Testing process of SDLCNN-ELM

where,
k consists of 1 dimension = [*Kmin*=1;*Kmax*=5], when calculating DL,
k value will be converted to 2**k* + 1.
FC1_Wjk consists of 1 x (5 x 7) = [-0.5;0.5]
FC2_Wjk consists of 1 x (7 x 7) = [-0.5;0.5]
FC3_Wjk consists of 1 x (4 x 7) = [-0.5;0.5]

Therefore, the length of the dimension of each particle is 113, the fitness value of which is the same as the (1/(1+ MAD)) value of the results of deep learning testing process. Figure 4 is the snippet code project for demo, and please see full code at our webpage: https://github.com/imamcs19/Improve-Deep-Learning-with-PSO.

Table 3. Representation of PSO particles for deep learning

$x_i(t)$	*k*	*FC1_Wjk*	*FC2_Wjk*	*FC3_Wjk*
..	..	..	..	..

```
function [MeanMADeachIteration]=FnMyIPSO_DLCNNeLM_TestConv(typeFeature,IterMaxPSO)

for t=0:IterMaxPSO
   % calculate value of w, c1, c2, r1, r2
   w=wmin+((wmax-wmin)*((tmax-t)/tmax));
   c1=((c1f-c1i)*(t/tmax))+c1i;
   c2=((c2f-c2i)*(t/tmax))+c2i;
   r1=rand(1,1); % random [0,1] element of uniform distribution
   r2=rand(1,1);

   if(t==0)
      % initialization position of particle
      X=repmat_SLCcLR_lower + (random('unif',0,1,pop_size,num_dim).*repmat_SLCcLR_delta);
      % initialization velocity of particle = 0
      V;

      % initialization Pbest and Gbest
      Pbest=X;
      [FitnessAllPbest,FitnessGbest,Gbest]=...
         FnGetFitnessNbestIndividuIPSODL(Pbest);
   else
      % update velocity
      %V=w*V+(c1*r1*(Pbest-X))+(c2*r2*(Gbest-X))
      V=(w.*V)+(c1*r1.*(Pbest-X))+(c2*r2.*((ones(pop_size,1)*Gbest)-X));
      V=FnBringtoRangeLowUpIPSODL(V,repmat_V_SLCcLR_lower,repmat_V_SLCcLR_upper);

      % update position
      X=X+V;
      X=FnBringtoRangeLowUpIPSODL(X,repmat_SLCcLR_lower,repmat_SLCcLR_upper);

      % calculate fitness of each Particles (X)
      [FitnessAllX,IndexSortingDesc]=FnGetFitnessIPSODL(X);

      % update Pbest and Gbest
      [FitnessAll_Update_Pbest,Fitness_Update_Gbest,Update_Pbest,Update_Gbest]=...
         FnUpdatePbestGbestIPSODL(FitnessAllPbest,FitnessAllX,FitnessGbest,X,Pbest,Gbest);
      FitnessAllPbest=FitnessAll_Update_Pbest;
      FitnessGbest=Fitness_Update_Gbest;
      Pbest=Update_Pbest;
      Gbest=Update_Gbest;

      % save mean of fitness each iteration
      MeanFitness(t)=mean(FitnessAllPbest);
   end
end
```

Figure 4. Snippet code of improve deep learning with PSO (deep PSO)

3. RESULTS AND ANALYSIS

Based on Figure 5, the ELM and DLCNNELM algorithm on rainfall data have the same tendency from all tests, but are still better than DLCNNELM, although in a fluctuating manner, ELM is better. This is because the weight carried out on each person is done randomly, and each time doing an experiment can be very different. When compared, the best result of the third is PSODLCNNELM (deep PSO). This algorithm uses PSO optimization techniques to get the same results with filtering processes, namely in the process of convolution, filing and pooling. Also the optimal weight value between layers in the Full Connected process.

The graph in Figure 6 shows the results of the convergence test. This convergence testing is done to determine the ideal iteration. The ideal iteration used in the dataset is 18. While the results of the single convergence test of obtained the lowest MAD value of the PSODLCNNELM (deep PSO) is 0.3418. On the graph, one thing that can indicate a good convergence test result is analysis the movement that obtained when each iteration increases. If every iteration there is a step by step sign of improvement movement of the MAD value, gradually and then when approaching toward the final iteration there will appear a convergent sign, ie by no more significant changes from the MAD value, so the test can be said to be successful.

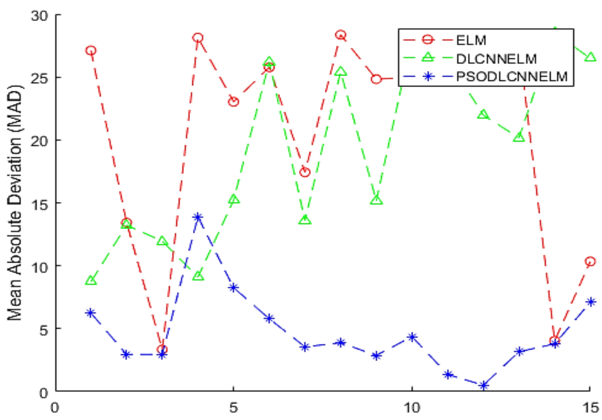

Figure 5. Comparison between ELM, DLCNNELM, and PSO-DLCNNELM (deep PSO)

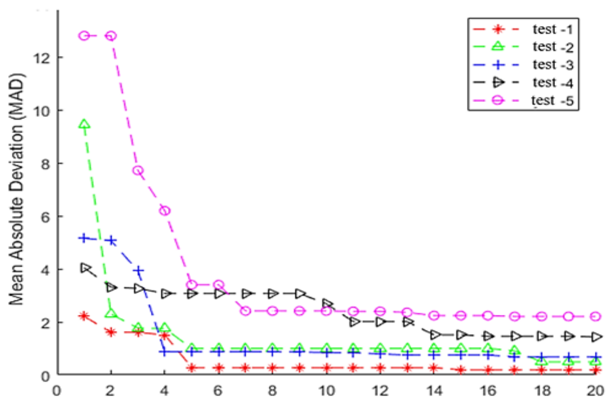

Figure 6. Convergence Test (5 times) of PSO-DLCNNELM (deep PSO)

4. CONCLUSION

Deep learning with PSO algorithm can be used to predict rainfall in Malang Regency where it works using feature extraction and transforming the data into image. The final result from proposed algorithm implementation has been successfully give a significant improvement as in the obtained test results, with lowest average value of MAD from PSODLCNNELM 0.3418. For more improvement, the next research can use more data and add some optimized particle dimension cluster.

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Imam Cholissodin, born in Lamongan on July 19, 1985, has completed his Master in Information Engineering FTIF ITS Surabaya in 2011. Since 2012, he has been active as a lecturer in the Department of Information Technology and Computer Science (a.k.a PTIIK) that since 2016 has become the Faculty of Computer Science (a.k.a FILKOM) Universitas Brawijaya (UB) Malang. He teaches several subjects such as Information Retrieval, Digital Image Processing, Probability and Statistics, Computer Graphics, Decision Support System, Artificial Intelligence, Data Mining, Big Data Analysis, GPU Programming, Evolution Algorithm, Swarm Intelligence, Pattern Recognition, and Mobile Programming. In addition to teaching, he is also active in the Intelligent System and Media, Game & Mobile Technology (MGM) in the Research Laboratory. From 2015 to 2019, he continued a research in the field of Big Data collaborated with the field of Economics along with a team of professors and students of the Faculty of Economics and Business (FEB) UB and Regional Development Planning Agency (BAPPEDA) of East Java Province under the theme of "Constructing the Blue Print of Open Data Utilization Initiation in Regional Development Planning" to support integrated Smart Governance (integrated with all existing systems from various platforms) based on Artificial Intelligence in the next few years and the development of the Core Engine Deep Learning and Big Data as General Library or Toolbox and package installer, and the support for programming languages and any OS platforms under the umbrella of Intelligent Laboratory Computation FILKOM UB research in backend and frontend computation on the desktop, web and mobile devices on the field of health, governance and the others that are locally-based and serverless with the technology of cloud computing in order to establish and create Advanced Technology "Smart App" products in the Industrial Revolution 4.0 and Society 5.0 eras for Humanity.

Sutrisno, born in Tulungagung on March 25, 1957, has completed his undergraduate education at the Electrical Engineering of Bandung Institute of Technology (ITB) graduating in 1982 and graduate education (S2) in the Electrical Engineering Master Study Program Universitas Brawijaya (UB) graduating in 2008. Since 1982, he has been a lecturer in the Department of Electrical Engineering, Faculty of Engineering, Universitas Brawijaya and was the Chairman of the Informatics Engineering Study Program from 2009 to 2011. In 2011-2016, he served as the Chairman of the Program (Dean) in the Information Technology and Computer Science Program (PTIIK)) Universitas Brawijaya that is now the Faculty of Computer Science (FILKOM) of Universitas Brawijaya. The subjects that he has taught include Distribution Systems, Electronics/Electrical Networks, Basic Programming, Advanced Programming, Algorithm Design and Analysis, Data Structure Analysis and Software Design.