Artificial Intelligence Technologies and Applications
C. Chen (Ed.)

doi:10.3233/FAIA231398

A NGO-RF-Based Evaluation Method for the Urgency Degree of Operation and Maintenance Work Order

Yu LIU[1], Donghao LI[2], Chao ZHANG[3], Linuo ZHANG[4]
China Telecom Research Institute China Telecom Co.,Ltd. Beijing, China

Abstract. For operators' operation and maintenance work, orderly completion of work orders according to the urgency degree of tasks can effectively improve the work efficiency of front-line maintenance personnel, ensure carrier service quality, and improve customer satisfaction. Based on the business attribute information of OAM work orders, this paper proposes multi-dimensional factors to determine the urgency degree of OAM work orders and build an urgency degree determination model based on NGO-RF. The simulation results show that the model accuracy is up to 95%. This model can be effectively applied to dispatching maintenance personnel to complete work orders by urgency degree in the operation and maintenance scheduling process.

Keywords. work order; urgency degree; random forest; NGO

1. Introduction

On-site maintenance is one of the primary maintenance tasks for operators to ensure customer service and enhance customer experience. With the development of digitalization and intelligence in the global information and communication industry, operation and maintenance (OAM) tasks of operators are delivered to maintenance personnel in the form of digital work orders.

In OAM work, the work order to be completed can be divided into different urgency degrees according to various factors such as completion time limit, content category, and implementation difficulty. A work order with a higher urgency degree has a greater impact on services and should be prioritized by maintenance personnel. At present, the OAM work order is mainly distributed manually according to the time limit of the work order. Recently research mainly focus on work order classification based on simple factors and path optimization of work order implementation, such as building a risk assessment model considering weather and equipment condition impact [1], studying the influence degree of various factors from the perspective of medium and long-timescale, meteorology, and

[1]Corresponding author: Yu LIU, China Telecom Research Institute China Telecom Co.,Ltd. Beijing, China; email: liuy200@chinatelecom.cn
[2] Donghao LI, China Telecom Research Institute China Telecom Co.,Ltd. Beijing, China; email: lidh14@chinatelecom.cn
[3] Chao ZHANG, China Telecom Research Institute China Telecom Co.,Ltd. Beijing, China; email: zhangc30@chinatelecom.cn
[4] Linuo ZHANG, China Telecom Research Institute China Telecom Co.,Ltd. Beijing, China; email: zhangln1@chinatelecom.cn

population to work orders [2], building the optimal path model base on the feature extracted from the GIS system [3]. Reasonable automatic determination of the urgency level of OAM work orders has become a critical issue in the process of work order dispatch.

In this paper, we first determine the factors that evaluate the urgency of the work order, then build a NGO-RF model to determine the nonlinear mapping relationship between the factors and urgency degrees of work orders, realizing the automatic determination and classification of the urgency degree of the work orders. Arranging maintenance personnel to complete maintenance tasks in an orderly manner based on the urgency degree of the work order can effectively improve the work efficiency of maintenance personnel, ensure carrier service quality, and improve customer satisfaction.

The structure of this paper is as follows: Chapter II determines the evaluation factors for evaluating the urgency degree, Chapter III introduces the NGO-RF-based evaluation model for the urgency degree of OAM work orders, Chapter IV shows the simulation results of the model, and Chapter V is the summary part.

2. Evaluation Factors for Evaluating the Urgency Degree of OAM Work Order

The urgency degree of OAM work order is affected by its characteristics, which is hard to determine according to a single factor. It is necessary to select the evaluation factors for determining the urgency degree of the work order from multiple dimensions. This paper proposes to take the time limit, the maintenance scenarios, customer types, the work order difficulty, whether co-built or shared, and the influence scale of customers as the factors to determine the urgency degree of OAM work order, to realize the accurate determination of the urgency level of the work orders.

2.1 Time limit

Each OAM work order has a completion time limit. Maintenance personnel should complete the specified maintenance tasks within the specified time limit. The urgency degrees of work orders are different under different time limits. The earlier the time limit of the OAM work order, the higher the urgency of the work order.

The common time limits of OAM work orders are 4/8/24/32 hours. Take the specific work order time limit as the value of the time limit factor to determine the urgency degree of the work order.

2.2 Maintenance Senarios

According to the actual operation and maintenance situation of the operator, the operation scenario can be divided into troubleshooting, risky operation, service provisioning, proactive maintenance, resource management, on-site cooperation, command task, and on-site support request. Different work order operation scenarios have different urgency degrees. Compared with the work order in routine maintenance scenarios, the work order in sudden failure scenarios needs an urgent process.

Assign different label values according to the impact of maintenance scenarios on the urgency of the work order. As shown in Table 1, set the label values of troubleshooting, risky operation, service provisioning, proactive maintenance, and resource management as 5, 4, 3, 2, and 1, respectively, where a label value of 5 indicates the highest urgency degree and a label value of 1 indicates the lowest urgency degree. The on-site cooperation, command task, and on-site support request scenarios support the other five scenarios. The work orders are associated with specific work orders and are not generated independently. The label value of the work order in the three scenarios should be consistent with the associated work order.

Table 1 Label and Values of The Factor "Maintenance Scenarios"

Value	Label							
	Troubleshooting	***Risky Operation***	***Service Provisioning***	***Proactive Maintenance***	***Resource Management***	***On-site Cooperation***	***Command Task***	***On-site Support Request***
Value	5(highest)	4	3	2	1(lowest)	Equals to the value of associated work order's label		

2.3 Customer types

The operation and maintenance of operators are mainly for government customers, enterprise customers, and public customers. Different types of customers have different requirements for maintenance services. Therefore, operators should give priority to providing timely and high-quality services to customers with high levels of importance.

Set different label values to reflect the impact of different customer types on the urgency of the work order. As shown in Table 2, set the label values of government customers, enterprise customers, and public customers as 3, 2, and 1, respectively, where a label value of 3 indicates the highest urgency degree and a label value of 1 indicates the lowest urgency degree.

Table 2 Label and Values of The Factor "Customer Types"

Value	Label		
	Government Customers	***Enterprise Customers***	***Public Customers***
Value	3	2	1

2.4 Difficulty of the Work Orders

The implementation of the OAM work order is affected by complexity and difficulty. Work orders with more difficulty require more maintenance personnel and maintenance time, so the urgency degree of the work order is higher.

The OAM work orders can be divided into buried optical cable type, climbing and descending type, and basic operation type, and the label value are set as 3, 2, and 1, respectively, which as shown in Table 3. The implementation difficulty of the ground cover optical cable work order is the highest, followed by the work order of climbing and descending, and the difficulty of the basic operation work order is the lowest.

Table 3 Label and Values of The Factor "Difficulty of The Work Orders"

Value	Label		
	Buried Optical Cable Type	***Climbing and Descending Type***	***Basic Operation Type***
Value	3	2	1

2.5 Whether Co-built or Shared

To maximize the utilization of equipment resources, some operators will co-build and share some resources and devices. When the object of a work order is co-construction and sharing equipment, there are more uncontrollable factors in the implementation and operation of work order tasks. Those work orders have a higher urgency degree and should be given to dispatching as soon as possible to leave more sufficient construction time for maintenance personnel.

Set the label value based on whether the work order involves co-construction and sharing. As shown in Table 4, the value of the work order with co-construction and sharing of the work object is 1, and the value of the work order without co-construction and sharing of the work object is 0.

Table 4 Label and Values of The Factor "Whether Co-Built or Shared"

Value	Label	
	Work order with device co-construction and sharing	***Work order without device co-construction and sharing***
Value	1	0

2.6 Influence Scale of Customer

The OAM of operators should ensure the user experience of most customers' communication networks as much as possible. When other objective conditions are the same, the OAM work order that involves a scale of customers is more urgent, and maintenance personnel should prioritize handling it.

Set the label value of urgent degree based on the number of affected customers. As shown in Table 5, assign the label value of the work order that affected more than 20,000, between 10,001 to 20000, between 5001 to 10000, equal or lesser than 5000 customers as 4, 3, 2, 1, respectively.

Table 5 Label and Values of The Factor "Influence Scale of Customer"

Value	Label			
	Affected customers more than 20,000	***Affected customers between 10,001 to 20000***	***Affected customers between 5,001 to 10000***	***Affected customers equal or lesser than 5000***
Value	4	3	2	1

3. Evaluation Model for Urgency Degree of OAM Work Order Based on NGO-RF

The random forest (RF) algorithm [4][5] introduces random sampling and random selection of split feature attributes based on the decision tree algorithm, making it a stronger generalization ability and faster convergence speed. But the RF, as a traditional classification algorithm, also faces the problem of hyper-parameter selection. The northern goshawk optimization (NGO) algorithm [6][7] has strong local and global search ability, which can be applied to the parameter optimization of RF model.

This paper build an urgency degree determination model based on NGO-RF. First, we constructs the evaluation model of the urgency degree of OAM work order based on the RF algorithm, taking the label value of evaluation factors for the urgency degree as input and the urgency degree level of OAM work order as output, to determine the nonlinear mapping relationship between the factors and the urgency levels of work orders.

Among them, the urgency level of the work order is divided into levels 1, 2, 3, and 4 in order of high and low, where level 1 indicates the highest urgency level and level 4 indicates the lowest urgency level. Then, use the NGO algorithm to optimize the hyper-parameter selection of the model to improve the accuracy and stability of the model.

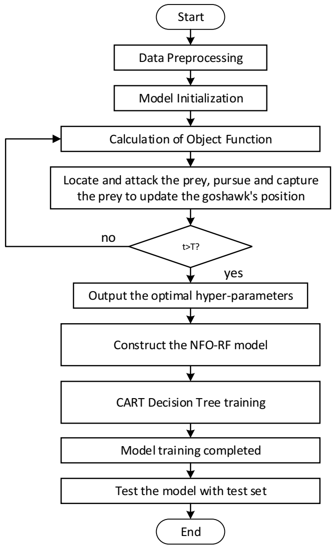

Figure 1. The construction flow chart of the evaluation model of urgency degree

Figure.1 shows the construction flow chart of the evaluation model of the OAM work order urgency degree based on NGO-RF, and the steps are as follows.

3.1 Data Preprocessing

Construct the data set for the model by amounts of related information of work orders, and divide the data set into a training set and a test set.

3.2 Model Initialization

Initialize the goshawk population location and iteration parameters of the NGO algorithm. Each goshawk has a corresponding initial position vector, as shown in equation (1), representing a set of possible solutions to the objective function.

$$X = \begin{bmatrix} X_1 \\ \vdots \\ X_i \\ \vdots \\ X_n \end{bmatrix}_{n\times m} = \begin{bmatrix} x_{1,1} & \cdots & x_{1,j} & \cdots & x_{1,m} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i,1} & \cdots & x_{i,j} & \cdots & x_{i,m} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{n,1} & \cdots & x_{n,j} & \cdots & x_{n,M} \end{bmatrix}_{n\times m} \quad (1)$$

Where, X_i is the position of the i^{th} northern goshawk, n is the population of the northern goshawk, m is the dimension, and $x_{i,j}$ is the position of i^{th} northern goshawk at j^{th} dimension.

3.3 Calculation of Objective Function

Using oob_{score} of RF algorithm as the objective function of NGO algorithm, the function is shown in equation (2)-(4).

$$oob_{score} = R^2 = 1 - \frac{RSS}{TSS} \tag{2}$$

$$RSS = \sum_{i=1}^{N}(y_i - f_i)^2 \tag{3}$$

$$\mathrm{TSS} = \sum_{i=1}^{N}(y_i - \bar{y})^2 \tag{4}$$

Where, N is the number of samples, y_i is the predicted output of the sample model, f_i is the target value of the sample, and $\bar{y}$ is the mean of the predicted output of the sample model.

3.4 Hunt of Northern Goshawk

1) Stage 1:Prey Recognition and Attack

The northern goshawk randomly selects its prey and quickly attacks it. Randomly selecting prey in the search space increases the exploration ability of the algorithm. At this stage, the search space is globally searched to identify the optimal hunting area. The function of prey selection and position updating are shown as equations (5) - (7).

$$P_i = X_k, i = 1,2,\cdots,N; k = 1,2,\cdots,i-1,i+1,\cdots N \tag{5}$$

$$x_{i,j}^{new,P_1} = \begin{cases} x_{i,j} + r(p_{i,j} - Ix_{i,j}), F_{P_i} < F_i \\ x_{i,j} + r(x_{i,j} - Iq_{i,j}), F_{P_i} \geq F_i \end{cases} \tag{6}$$

$$X_i = \begin{cases} X_{i,j}^{new,P_1}, F_i^{new,P_1} < F_i \\ X_i, F_i^{new,P_1} \geq F_i \end{cases} \tag{7}$$

Where, P_i is the position of the i^{th} northern goshawk, k is a random integer in the range [1,N] not equal to i, r and I are random numbers in search and iteration, the range of r is [0,1],I is 1 or 2, $x_{i,j}$ is the current position of i^{th} northern goshawk at j^{th} dimension, $p_{i,j}$ is the current position of i^{th} prey at j^{th} dimension, F_i is the objective function value of the i^{th} northern goshawk, $x_{i,j}^{new,P_1}$ is the position of i^{th} northern goshawk at j^{th} dimension updated in stage 1, F_i^{new,P_1} is the objective function value of the northern goshawk updating in the stage 1.

2) Stage 2: Pursuit and Escape

After the northern goshawk attacks its prey, the prey will try to escape. However, the northern goshawk is agile and extremely fast, and can pursue and eventually capture its prey in almost any situation. The pursuit behavior increases the NGO algorithm's local search ability in the search space. The hunting radius R and position update rule of northern goshawk in stage 2 are shown in equation (8) - (10).

$$R = 0.02\left(1 - \frac{t}{T}\right) \tag{8}$$

$$x_{i,j}^{new,P_2} = x_{i,j} + R(2r-1)x_{i,j} \tag{9}$$

$$X_i = \begin{cases} x_{i,j}^{new,P_2}, F_i^{new,P_2} < F_i \\ X_i, F_i^{new,P_2} \geq F_i \end{cases} \tag{10}$$

Where, t is the current number of iterations and T is the maximum number of iterations, $x_{i,j}^{new,P_2}$ is the position of i^{th} northern goshawk at j^{th} dimension updated in stage 2, F_i^{new,P_2} is the objective function value of the northern goshawk updating in the stage 2.

In the process of hunting prey, the goshawk constantly optimizes its position to approach the prey, and finally determines the optimal position of the goshawk from the prey.

3.5 NGO Termination Judgment

Determine whether the NGO algorithm has reached the maximum number of iterations. If yes, output the optimal hyper-parameter found by the algorithm. Otherwise, repeat steps *C* and *D*.

3.6 NGO-RF Model Construction

Use the optimal hyper-parameters obtained by NGO algorithm to construct the RF model. According to the principle of the Bagging algorithm, randomly select *B* sub-training sets containing n ($n \leqslant m$) samples in m sample training sets with put back. Each sub-training set corresponds to the training data of a CART decision tree.

3.7 CART Decision Tree Training

Each sub-training set grows separately into a CART decision tree [8]. To improve the randomness of node splitting, ensure the independence and diversity of the single subtree, and enhance the generalization ability of the model, w attribute features are randomly selected from the W candidate attribute features at each split node of the CART decision tree (usually $w = \log_2 W$). On each split node, the optimal feature is selected from w attribute features according to the minimum principle of Gini coefficient [9] for branch growth, and each decision tree is fully grown without pruning operation.

3.8 Model Training

According to the classification results of B CART decision trees, the final NGO-RF model results were determined by voting, and the model training was completed.

3.9 Model Testing

Use the test set to verify the effectiveness of the NGO-RF model and evaluate the model performance.

4. Simulation and Result Analyze

Part of the feature data of OAM work orders are shown in Table 6, which are used as the experimental data of the model.

Table 6 The Feature Data of OAM Work Orders

Value	Label						
	OAM work order ID	***Time limit***	***Maintenance senarios***	***Customer types***	***Difficulty of the work orders***	***Whether co-built or shared***	***Influence scale of customer***
Value	2023050112041309	8	Troubleshooting	Government Customers	Climbing and Descending Type	co-construction and sharing	more than 20,000
Value	2023050307090119	32	Service Provisioning	Public Customers	Basic Operation Type	without co-construction and sharing	5,001 to 10000
Value	2023050401111322	24	Resource Management	Enterprise Customers	Basic Operation Type	co-construction and sharing	more than 20,000
Value	2023050807021814	4	Risky Operation	Public Customers	Basic Operation Type	without co-construction and sharing	lesser than 5000
Value	2023051005021814	24	Resource Management	Public Customers	Basic Operation Type	without co-construction and sharing	lesser than 5000

In this paper, we use the decision tree, RF, and NGO-RF algorithms as the evaluation models for the urgency degree of OAM work orders, and design three sets of comparative experiments to verify the effectiveness of our model. Select 1,000 samples as the data set for model training and verification, where 700 samples for the training set and 300 for the test set. The accuracy of the three different models for evaluating the urgency level of work orders is shown in Table 7.

Table 7 The Accuracy of The Evaluation Model of The Urgency Level With Different Algorithms

Accuracy	Algorithm		
	Decision Tree	***Random Forest***	***NGO-RF***
Accuracy	90.67%	92.33%	95.67%

The scatter diagrams between the predicted result and the actual value of the test set of three models are shown in Figure. 2 to Figure. 4.

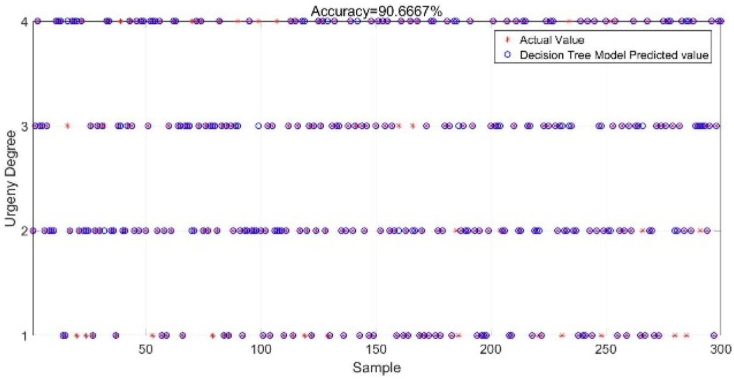

Figure 2. The output results of the decision tree model

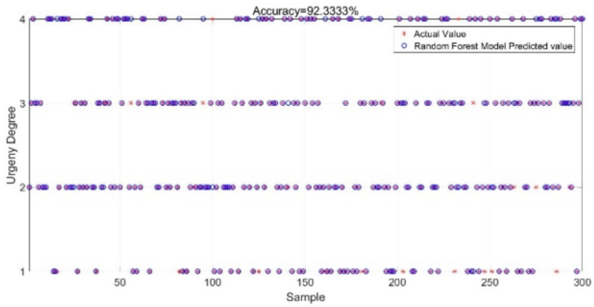

Figure 3. The output results of the RF model

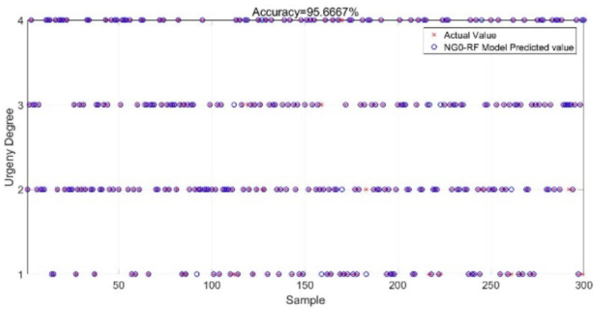

Figure 4. The output results of the NGO-RF model

The results show that the NGO-RF model proposed in this paper can effectively improve the accuracy of work order urgency degree evaluation.

5. Conclusions

Due to the incomplete factors and simple model of the evaluation method of the urgency degree of OAM work order, this paper proposes an evaluation model of the urgency degree of operation and maintenance work order based on NGO-RF. Firstly, establish 6-dimensional factors to comprehensively measure the urgency characteristics of work orders. Then, Construct the RF classification model, and optimize the hyper-parameter selection of the RF classification model by NGO algorithm, to determine the nonlinear mapping relationship between the evaluation factors of the urgency and the urgency degree of work orders. The experimental results show that the model established in this paper can accurately evaluate the urgency degree of the work orders. In the production environment, the scheduling system can make decisions according to the urgency degree of work orders from the NGO-RF model, and dispatch the work order with a higher urgency degree to the maintenance personnel, which can ensure carrier service quality and improve customer satisfaction.

References

[1] J. Liu, S. Hu, D. Chen and B. Li, "A dispatching operation risk assessment method based on real-time probabilistic model," 2013 IEEE International Conference of IEEE Region 10 (TENCON 2013), Xi'an, China, 2013, pp. 1-4, doi: 10.1109/TENCON.2013.6718497.

[2] J. Lu, J. Ji and X. Xu, "Analysis on Influencing Factors of Repair Order of Power Supply Station based on Grey Correlation Analysis," 2022 4th Asia Energy and Electrical Engineering Symposium (AEEES), Chengdu, China, 2022, pp. 730-734, doi: 10.1109/AEEES54426.2022.9759700.
[3] Y. Li, J. Liao, R. Sun and J. Tan, "Distribution Network Intelligent Operation and Maintenance Dispatching Method Based on GIS Data Analysis and Optimal Path Model," 2022 2nd International Conference on Electronic Information Technology and Smart Agriculture (ICEITSA), Huaihua, China, 2022, pp. 287-293, doi: 10.1109/ICEITSA57468.2022.00056.
[4] Peilin Li."Credit Card Fraud Detection Based on Random Forest Model." Academic Journal of Computing & Information Science 5.13(2022). doi:10.25236/AJCIS.2022.051309.
[5] Yu Xinliang,and Zeng Qun."Random forest algorithm-based classification model of pesticide aquatic toxicity to fishes." Aquatic Toxicology 251.(2022). doi:10.1016/J.AQUATOX.2022.106265.
[6] El-Dabah Mahmoud A., et al."Photovoltaic model parameters identification using Northern Goshawk Optimization algorithm." Energy 262.PB(2023). doi:10.1016/J.ENERGY.2022.125522.
[7] Jasim Mohammed Jasim Mohammed, et al."Automated Colonic Polyp Detection and Classification Enabled Northern Goshawk Optimization with Deep Learning." 75.2(2023). doi:10.32604/CMC.2023.037363.
[8] Yanyan Han, Ke Xu,and Jiayin Qin."Based on the CART Decision Tree Model of Prediction and Classification of Ancient Glass-Related Properties".Proceedings of 2023 International Conference on Mathematical Modeling, Algorithm and Computer Simulation (MMACS 2023).Ed.. , 2023, 19-28.
[9] Gupta Kapil."An integrated batting performance analytics model for women's cricket using Principal Component Analysis and Gini scores." Decision Analytics Journal 4.(2022). doi:10.1016/J.DAJOUR.2022.100109.