An Anomaly Intrusion Detection on Database Operation by Fuzzy ART Neural Network

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Abstract*-Due to the rising and flourishing of the information technology, the outsourcing of enterprises can reduce the system development time and cost so that many enterprises select information system outsourcing instead of development by themselves. The question then arises as to protect company security information and to monitor the detail operation of database system. This paper discusses the security question of information outsourcing and uses the Adaptive Resonance Theory neural network to build a model of company security judgment. The mode is constructed by ART network that is based on analysis the log file of connections from client sides to the database of server side. Finally, an experiment indicates our system have good results on anomaly intrusion detection of database operation.*

Keywords: *outsourcing, ART, intrusion detection, database security, audit log*

1. Introduction

The information processing has become the basic operations of the corporation. Due to convenience of computer processing so that it arises the hacker attack, babbling enterprise security, and insider misusing computer system problems. The security of corporation confidentiality and enterprise information system is affected seriously.

Outsourcing is the popularity application of corporation information. The main object of outsourcing is to reduce the cost of information and to get the application system from the professional company but the risk of system outsourcing is high. For reducing the risk of outsourcing, one way is to define the contract with the outsourcing company; the other way is to commend the third-party experts to monitor the action of outsourcing company. If the corporation has a simple useful protecting system for the corporation security information, it will enhance the protection about corporation security information.

Due to the rising and flourishing of the Internet, the computer applications in corporation are more aplenty than previous applications. The behaviors of using information system were changed by the Internet system. For example, the information system of corporation was changed from closed system to opened system. The Internet architecture is added to the corporation information system. Users can access the information system from anywhere but crackers can follow the same way to connect to the corporation host computer so that the security risk of the enterprise is arising.

According to CERT annual statistical data from 2000 to 2003[1], the network attacked event growth with each passing day. Carter and Katz [2] indicated that system administrator should focus the attention on the insider illegal used rather than hacker intrusion from the outer. Thus, the duty of system manager is to monitor both of intrusions; one is outer hacker intrusion and the other is misuse used of insider user.

The rising and flourishing of Internet technologies are improving, likewise network attack events are rising. The database management system is important in corporation information system. The paper focuses on the database safety. The processing method is similar to the intrusion detection model. The system processes the database linked log by neural network technology and analyzes the log file to find the intrusion. By monitoring the database access log, the system can find out anomaly intrusions on database operation.

The remainders of the paper are organized as follows. In Section 2, the relative technologies are briefly described. The Fuzzy ART Neural Network is presented in Section 3. In Section 4, the database intrusion detection is described. In Section 5, experimental results are illustrated. Finally, we make conclusions in Section 6.

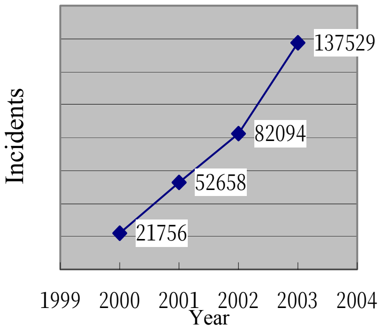


Figure1 The statistic of incidents by CERT

2. Related work

The concept of intrusion detection is published on James P. Anderson 1980's reports[3]. Afterward, many definitions about intrusion were reported. For example, Gaham[4] defined the intrusion is "An intrusion is somebody, hackers or crackers, attempting to break into or misuse your system. The intrusion detection system is to find the intruder using any method to protect the computer system." Based on the concept, the types of intrusion detection system can be classified by techniques[1] and detection methods.

2.1 The classification of intrusion detection system by techniques

The technique of intrusion detection system is to detect the feature change or to compare the profile of user general activity[5]. The intrusion detection includes three modes:

(a.) Misuse intrusion detection

The detecting method finds the feature that expert predefined. The advantage of misuse intrusion detection is fast detecting and lowly error rate but the weakness is while the feature not previously defined, the system unable to find the intrusion.

(b.) Anomaly intrusion detection

The detecting system will build the users' profile model on the user general activity. The anomaly intrusion action is defined that users' behaviors exceed the profile module. The good quality of the anomaly intrusion detection is that it can find new intrusion action but it weaknesses are to build profile module will waste time and the error rate of intrusion detection is high.

(c.) Hybrid and mixed intrusion detection system

The method mixes both of the misuse and anomaly methods. For explicit intrusions, the misuse method is used to detect intrusion; moreover, the other intrusions the anomaly method is used to detect intrusion. Appling the hybrid method, the major detecting method must be selected even misuse or anomaly intrusion detection. The advantage of hybrid method is high correcting detection rate but the cost and detection time are higher than using misuse or anomaly only.

2.2. The intrusion detection system was classified by detection method

From the technological views, the intrusion detection is one of information classification problems. Scilicet, the method of classification can be applied to the intrusion detection. Several classifications of intrusion detection methods are shown as follows.

(a.) Statistic Analysis

In statistic analysis method[6], the intrusion detection system will record the status of computer general behavior and the frequency of operation, and then the system infer whether the user's actions are legal or not by statistic information.

(b.) Neural Network

The intrusion detection system can be built by a neural network model so that it could be quickly computing[7]. Whether using the supervised learning network or unsupervised learning network, all the intrusion detections can be applied to misuse or anomaly method but how to select a good network model and how to select feature are challenges

(c.) Rule-Based Analysis

The computer security expert created the rules of the computer safe or unsafe operations[8]. The intrusion detection system judges the user profile through the rule base. The expression of rule base includes positive expression and negative expression. The weak of rules processing is rule matching is time consume.

(d.) Bayesian Network

Using Bayesian network to display the probability of events and behavior[9], the intrusion detection system judges the behaviors by Bayesian network. The key points are the distribution of probability of events and feature. If the feature unable to be expressed by the probability, it is not suitable. If the intrusion detection system applies the Bayesian network, it can inference the anomaly detection function.

(e.) Finite State Machine

The system operations can be expressed as the state by finite state machines[10]. Experts can define the transfer condition of the intrusion. The method's bottleneck is how to set the transfer condition.

(f.) Data Mining

The association rules of mining techniques are also applied in intrusion detection[11]. The intrusion detection system uses the feature of fields to construct association rules, such as the connection time of user, the IP address, the called or calling program etc. First, the system finds the key point record from the network behavior record, and then mining by the association rules, it can be applied to the intrusion detection system. The weakness of data mining method is how to select important data and how to set the threshold value are still hard problems.

3. Fuzzy ART

In the paper, a fuzzy ART, Adaptive Resonance Theory [12][13], neural network is used to detecting anomaly Intrusion of database operation. It is an unsupervised learning method. The input value of ART is binary but the ART-2 the input values is the real values between 0 and 1. ART-2 Network is used in our system.

The theory of ART is from the cognition. First, the network gets the training sample from research domain, and then the network will learn to form the inside clustering rule. After the training phrase, the network can classify the new example. If the example is not included at existing clusters, the network will generate a new cluster. The operation of ART is similar to people brain neural system. Not only learns the new example, but also reserves the old memory cells. The ART has both feature of stability and plasticity.

In order to solve the antinomy of stability and plasticity, the ART network will adjust the vigilance value. The method of controlling vigilance test values is described as follows.

(a.) When the feature of new example is similar to existing clusters, the vigilance test is passed. The network modified the memory cells of the existing cluster, let the network can recognize the existing example and new example so that the stability is filled.

(b.) IF the feature of new example is not similar to existing clusters, the vigilance test is not passed. The system creates the new memory cells for the new example. The system meets the plasticity it can learn new examples quickly.

The architecture of ART can be divided three parts which are described as follows.

(a.) Input layer: The input data is training examples. The number of input vectors is decided by question domain.

(b.) Output layer: It presents the result of trained network. The number of output units was increased by the training epoches. The training is ended when the output units are stably fixed in a steady number.

(c.) Weight connections: It connected the input layer and output layer. Every connection is connected between the input unit and the output unit has two direction links. The input and output units are fully connections. The two link directions, input units to output units and output units to input units, have different meaning. The link of input-to-output is W^b. The values of W^b can be used to calculate the value from input vector to one of unit of output layer. The output unit has max corresponding value will be used for vigilance test. The values of W^b are real numbers between 0 and 1. The corresponding value of output unit "j" is described in formula (1).

$$\text{corresponding value : net[j]} = \sum_{i} W^b[i][j] \times X[i] \text{ --(1)}$$

The weighted value of output-to-input is W^t. The values of W^t are used to calculate the similar value of the input vector of trained examples connected one unit of output layer. The similar value decided the test that an output unit is tested by vigilance value. The values of W^t are real numbers between 0 and 1. The formula of similar value of output unit j is described as follows (2).

$$\text{Similar value } : \mathrm{V_j} = \frac{\|\mathrm{W_j^t} \times X\|}{\|X\|} = \frac{\sum_{i} W^t[i][j] \times X[i]}{\sum X[i]} \text{ ------(2)}$$

The relation of W^t and W^b is listed in formula (3).

$$W_{ij}^{b} = \frac{W_{ij}^{t}}{0.5 + \sum W_{ij}^{t}} \text{ -------------- (3)}$$

The ART network operates the vigilance test based on the corresponding values. It does vigilance test for each output unit from one with maximum corresponding value to the minimum corresponding value with. In ART network, if the output layer unit has high corresponding value, it will have high similar value, too. In ART network, the number of output layer units will be affected by the vigilance test values. The higher vigilance value dues to the number of output units incremental. The vigilance value also controls the stability and plasticity of ART network. The higher vigilance value the higher plasticity is; furthermore, the ART network will increase the number of clusters. On other hand, the lower vigilance value will lead to clusters less.

4. The database intrusion detection

In this paper, the processing data, database connection information, got from land office of Taichung city in Taiwan. First, the log file of connection records were extracted from database on server side which would record the client sides connection information. And then, the connection record transfer into numerical data. Finally, all numerical data mapped to the range from 0 to 1 by linear function requested for the input of neural network of ART-2. The fuzzy art model was created on MATLAB software. On the neural model, first, the numerical data was put into the input vector of the neural network. Second, the vigilance value and the learning rate were set. And then, the clustering results about the connection records were gotten. Finally, the system will modify the vigilance value and learning rate to get a better clustering result. The phrase of experimentation is described as Figure 2 where α, β are two values of number of clusters.

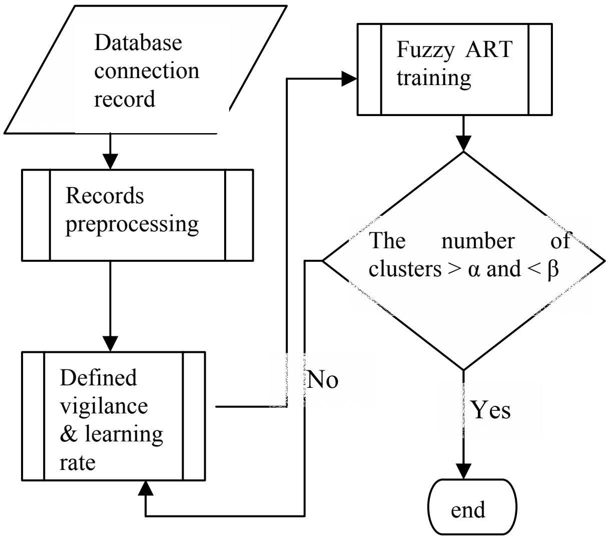

Database connection record
Records preprocessing
Defined vigilance & learning rate
Fuzzy ART training
The number of clusters > α and < β
No
Yes
end

Figure 2 The system architecture

The database on server side in our experiment is Oracle version 7. The format of connection record[14] is given as follows.

TIMESTAMP*CONNECT DATA

[* PROTOCOL INFO] *EVENT

[*SID]*RETURN CODE

The data of connection record can be divided into several fields.

(a.) TIMESTAMP: It records the time that client computer connected to the database server.

(b.) CONNECT DATA: It includes the detail information of client compute. For example, the user name of login, the used program that connected to database server, and machine name of client computer etc.

(c.) PROTOCOL INFO: It records the network protocol used in the connection. If this time used the TCP network protocol, the information would include the network address.

(d.) Event: It records why to build this connection? In many cases, it is to build the connection for database but sometimes it may start or stop the listener program.

(e.) SID: It indicates which database was used.

(f.) RETURN CODE: The return code is 0 if the connection is success.

An example of a connection record is specified.
“10-MAY-95 14:16:21*
(CONNECT_DATA=(SID= reltest) (CID=
(PROGRAM=C:\ORAWIN\BIN\PLUS31.EXE)
(HOST=WINDOWSPC)(USER=CCLOW))
*(ADDRESS=(PROTOCOL=tcp)(HOST=144.25.
23.246)(PORT=3366)) *establish*reltest*0”

The time stamp of this connection record is at the 14:16:21 on May 10,1995. The client computer name is “WINDOWSPC”. This connection is connected to the reltest database. The user who login the client computer is CCLOW and the user used PLUS31.EXE program. The used network protocol was TCP with port 3366. The network address of the client computer is 144.25.23.246. The result of this connection is success.

We can get information form connection record as Table 1.

Table1 the analysis table of connection record

No	Item Name	Data Content
1	Time Stamp	10-MAY-95 14:16:21
2	User Name	CCLOW
3	Client computer Name	WINDOWSPC
4	SID	Reltest
5	Program name	PLUS31.EXE
6	Network address	144.25.23.246
7	Network protocol	TCP

In our experiment did not use DHCP protocol. The network address was selected to district the client computers. Furthermore, the system uses time stamp, user name, database name, the network address of client computer, program name and network protocol as feature and then they were input into the ART network after they were transferred to numerical values. Finally, the Fuzzy ART neural network did the clustering work to find anomaly intrusion operations.

The methods of transform the text feature to values are described as follows.

(a.) For two holidays in every week, the basic connection record uses week as unit. The connection time formula as:
Tc = The number of day in a week $D1$(day)+
Connection Time $T1$(hours) +
Connection Time $T2$(minutes)
The value of timestamp is gotten as following formula.

$$F_{Tc} = \frac{Tc \times 24 \times 60 + T1 \times 60 + T2}{7 \times 24 \times 60}$$

(b.) The maximum number of user names (Un), program names (Pn) network protocols (Nn) and SID(Sn) will be represented as S_t, and then the four types of feature will be extracted by the following formulas.

St = Max(the number of Un|Pn|Nn|Sn)

$$F_{Un} = \frac{1}{St} \times Un$$

$$F_{Pn} = \frac{1}{St} \times Pn$$

$$F_{Nn} = \frac{1}{St} \times Nn$$

$$F_{Sn} = \frac{1}{St} \times Sn$$

(c) The connections data of land office are an enterprise local network. We select the right most two decimal number of network address as feature. For example, an IP address is represented as A.B.C.D., and then the feature is gotten by the following formula.

$$F_{IP} = [\mathrm{C} \times 255 + \mathrm{D}]/(255 \times 255 + 255)$$

5. Experiment

The data sources in the experiments were extracted from a land office, collecting during the days of 2004/02/28 to 2004/04/02. After filtering fail connection records, 49973 records were used to test during the experiments.

Figure 3 shows the different learning rate and vigilance value clustering results. The mean of A3NET7 in Figure 3 stands for learning rate is 0.3 and vigilance value is 0.7. While result of the vigilance value has max impact, the learning rate only had minimum impact. Finally, the learning rate is set to 0.5 in the experiment. For different vigilance values, the number of clustering and the number of records of each cluster are drawn in Figure 4.

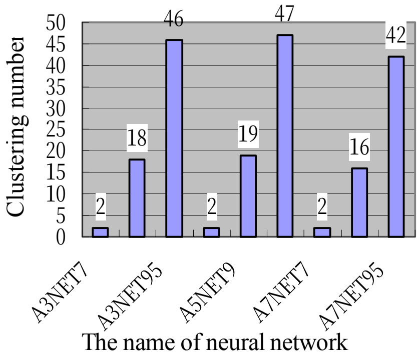
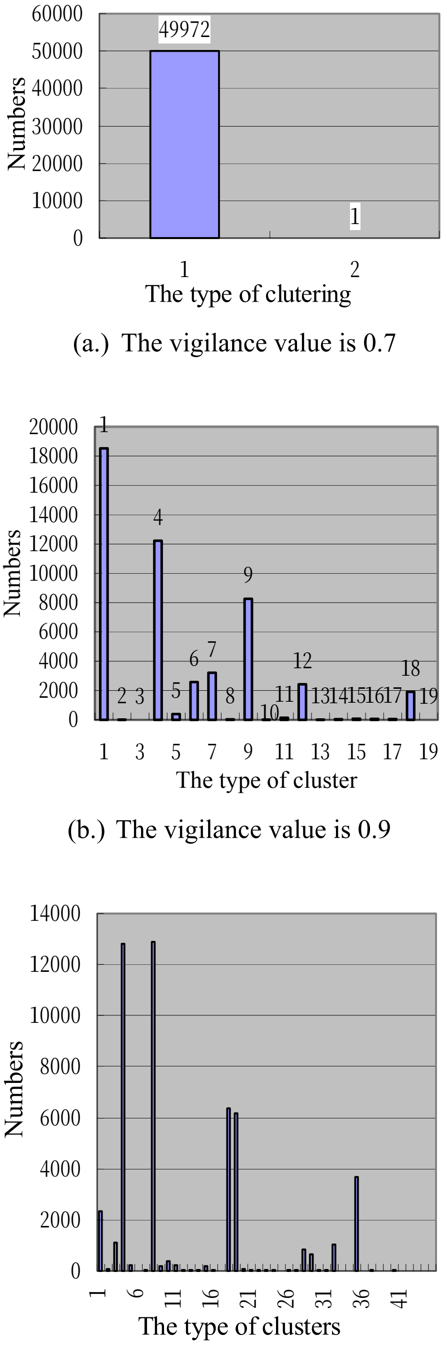


Figure 3 The different learning rate and vigilance value clustering results



(a.) The vigilance value is 0.7

(b.) The vigilance value is 0.9

(c.) The vigilance value is 0.95

Figure 4 the scattered diagram on different vigilance value

From the clustering diagram of different vigilance values, found that more number of connection records distributed in a few clusters while vigilance value is 0.9 or 0.95. If the threshold, the number of record in a cluster, is less than 100, only 310 records are remainders from the 49973 records while vigilance value is 0.9. Likewise, 839 records are remainders while vigilance is 0.95.

The system manager only needs to trace the remainder records and to analyze whether the database connection is safe or not. The reducing rate is 0.006 or 0.016. It is a real advantage for system manger. Furthermore, we can find out the importance of feature are network address, user name, program name, and time stamp. It is an important guide for developing database intrusion detection system when using in misuse mode. From the experiment results, we could find few programs seem never connected database. After tracing the connection records, the system manger found the program was developed by outsourcing company. It can illustrate the method of an anomaly intrusion detection on database operation by Fuzzy ART is efficient.

6. Conclusions

In this paper, a Fuzzy ART neural network was applied to database operation security management. By monitoring the user behavior, the system can protect enterprise information system. The analysis the data includes user name, the network address of client, the connection building time, database name, used program, used protocol and so on which were extracted from the log file of database connection record. The feature is transformed to real number for Fuzzy ART input unit. There are more than 99% of connection record distribute in a few clusters, only few connection records distributed in the other cluster. The database administrator only needs to trace the few connection records. The system can great reduce the loading of database administrator of analysis thousands of database record.

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