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Research on the Security of Computer Platforms HMM-based Fault Diagnosis

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Abstract: Health management has been a technology which is widely used in the area of aerospace and weaponry in recent years to monitor the state and repair the failure of a system or component parts. According to the problems of safety computer in CBTC, the study studies the health management technology of safety computer platform in depth such as state monitor and fault diagnosis, using the "soft" failures related to the hardware failures. First, this study introduces the concept of Health Management and expounds the model with Condition-Based Maintenance as the breakthrough point. 1207231545 (HMM) is introduced to the fault diagnosis of safety computer platform, because of the similarities between recognition algorithm and fault diagnosis and its successful application in the field of pattern recognition. Second, based on demand analysis of safety computer in CBTC, simulation safety computer platform of 2-out-of-2 redundant structure is designed using the common computers. The implementation of health management based on Hidden Markov Model can well solve Condition-Based Maintenance problem of safety computer platform. It has certain reference value to health management study of other safety system.

Key words: Safety computer, health management, HMM, state monitor, fault diagnosis

INTRODUCTION

HMM speech signal as a statistical model, the speech processing are now widely in various fields of application. As early as 100 years ago, the Markov chain has been known to engineers. However, because of the lack of an identification signal enables HMM parameters and effective way to achieve the best match, HMM has not been very good application. Over the last decade, HMM technology both in theory and in practice have been a great development. Currently HMM has a digital signal processing is an important field of research, particularly in the field of speech recognition. Speech signal recognition flowchart shown in Fig. 1.

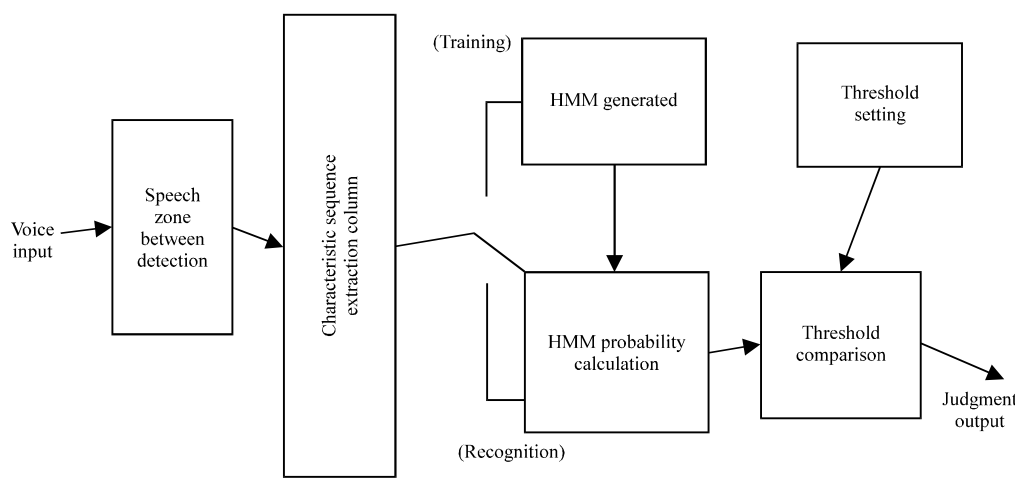

Fig. 1: Flow chart of speech recognition

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Entire recognition process is divided into two stages, namely the training phase and the recognition phase. In the training phase, the pronunciation of each different person, be tested pronunciation extracted feature vector sequence, vectors based on these characteristics, the use of HMM acoustic model to correspond. Because the provisions pronunciation statement is determined in advance, so the time structure of the feature vector is determined using HMM can better reflect the time structure characteristic feature vectors. In recognition stage, first be tested also extracted from the speech signal effective feature vector sequence and then use the trained HMM acoustic model to calculate the probability that the vector sequences generated, based on a similar criterion to determine the recognition results. Similar maximum probability value corresponding to the model is generated by the tester is to be identified as the training phase of the speaker pronunciation (Kong and Lu, 2010). Furthermore can the resulting probability is compared with a threshold value which value is greater than (or equal to) the threshold value is accepted as sound I is less than the threshold value are rejected as the voice of another person in order to achieve speech recognition function.

HMM successful application in the field of speech recognition to obtain constantly expanding application areas. Almost signal processing and pattern recognition can be found in every aspect of HMM traces, such as identity field, the field of fingerprint identification, gene identification fields. In short, HMM applied to time series modeling and dynamic process timing mode with a strong ability to distinguish, especially for non-stationary signal analysis repeated poor reproducibility.

Given the speech recognition and fault diagnosis in pattern classification, recognition of similarities, many scholars are committed to HMM applied to performance monitoring and fault diagnosis in industrial processes and achieved good effect. For example: Professor Smyth NASA's success with HMM carried out on the ground to monitor the health status; Bemard such as the University of Washington who made use of the tool wear state HMM real-time monitoring; Ocack Case Western Reserve University and Loparo proposed HMM-based vibration signal in bearing fault diagnosis;National University of Defense Technology, Professor xinminliu Use HMM aachieved using intermittent fault diagnosis and false alarm suppression of electromechanical systems and obtain good monitoring results.In addition, HMM is advanced life cycle engineering center at the University of Maryland, USA (CALCE) identified as one of the classic model of the field of electronic health management technology.

RESEARCH ON THE SECURITY OF COMPUTER PLATFORMS HMM-BASED FAULT DIAGNOSIS

Fault diagnosis refers to the system operation and anomalies judgment and restoration activities provide the basis for the system failures, including fault detection and fault location two processes (He and He, 2002). Accurately locate the fault, is another important application of health management. CBTC system security computer platforms, communicate with each other via Ethernet between each unit, work process, inevitably will be all kinds of interference. Interference affects normal communication systems, resulting in cycle time work obstruction communication problems affecting the system when. When affected to a certain extent, micro-cycle consumption of normal working hours exceed the micro-cycle timing of time, the impact of synchronization processing unit PU1 and PU2, causing the two aircraft out of step. This chapter computer simulation platform to simulate the actual safety of CBTC system security computer platforms, from the perspective of signal interference, simulated faults occur, conduct research system fault diagnosis.

Speech recognition will be widely used in the field of HMM, introduced to fault diagnosis in computer security, mainly because of the following reasons:

- HMM applies doubly stochastic processes.HMM itself contains two processes, Not only the state transition is random and each state is a value corresponding to the observed random process.Without knowing the state of the process of change, the sequence to be deduced by observing the presence and characteristics of the state.By the last chapter shows that failure of process safety systems and other electronic computer platform is a typical double stochastic process, the potential failure of equipment can not be seen directly, but it can be used to identify the occurrence of faults by monitoring the corresponding predicted signal
- HMM has an easy training characteristics. Is a typical HMM model parameters, the parameters can be estimated by the effective training algorithms. Troubleshooting Security variety of computer platforms, because the same type of failure are also different. Use Baum-Welch algorithm can be easily trained for each fault HMM, establish security troubleshooting computer platform library for future fault location provided for convenience only
- Separate multiple models. A plurality of independent HMM system to describe the different types of

failure is easy. That corresponds to a fault of each HMM which ensures the accuracy of the model diagnostics. In addition, when there is a new fault types, simply add an HMM without affecting the other has trained HMM

HMM-BASED COMPUTER PLATFORM SECURITY PRINCIPLE OF FAULT DIAGNOSIS

HMM-based fault diagnosis familiar with condition monitoring based on similar principles HMM, Fault diagnosis process is shown in Fig. 2.

Troubleshooting process includes three aspects:

- Extraction and pre-processing of state observation data With condition monitoring process, the right to extract the raw sample data is an important part of the troubleshooting process. Since, the original data is often redundant and high-dimensional features, direct HMM training will reduce accuracy.In addition, fault diagnosis need to extract data from different observations of failure, type structures observed data may differ, so in fault diagnosis, the more necessary to preprocess the raw observation data to meet the needs of subsequent treatment while convenient data transmission and storage

  Diverse types of system failures, in order to improve diagnostic accuracy, the system needs to study all the failure modes and each failure to extract the corresponding observational data. In addition, the system needed to extract the normal state of observational data as a reference
- **Training of failure mode of HMM:** Use of the observation sequence obtained,By Baum-Welch algorithm likelihood estimation of model parameters, in order to improve the stability of the HMM, we need a revaluation algorithm multiple observations of the sequence.

  Need training system for all failure modes HMM, constitute a system fault diagnosis libraries. The basic idea is that when troubleshooting system failures, with observational data to find fault diagnosis database corresponding failure modes HMM
- **Fault diagnosis decision:** When a fault occurs, the observational data into the fault diagnosis system libraries, using a forward-after calculating the observed data in each failure mode likelihood or probability of $\lambda = (\pi, A, B)$ to the algorithm Viterbi algorithm, the maximum likelihood probability HMM decided the current system the fault type

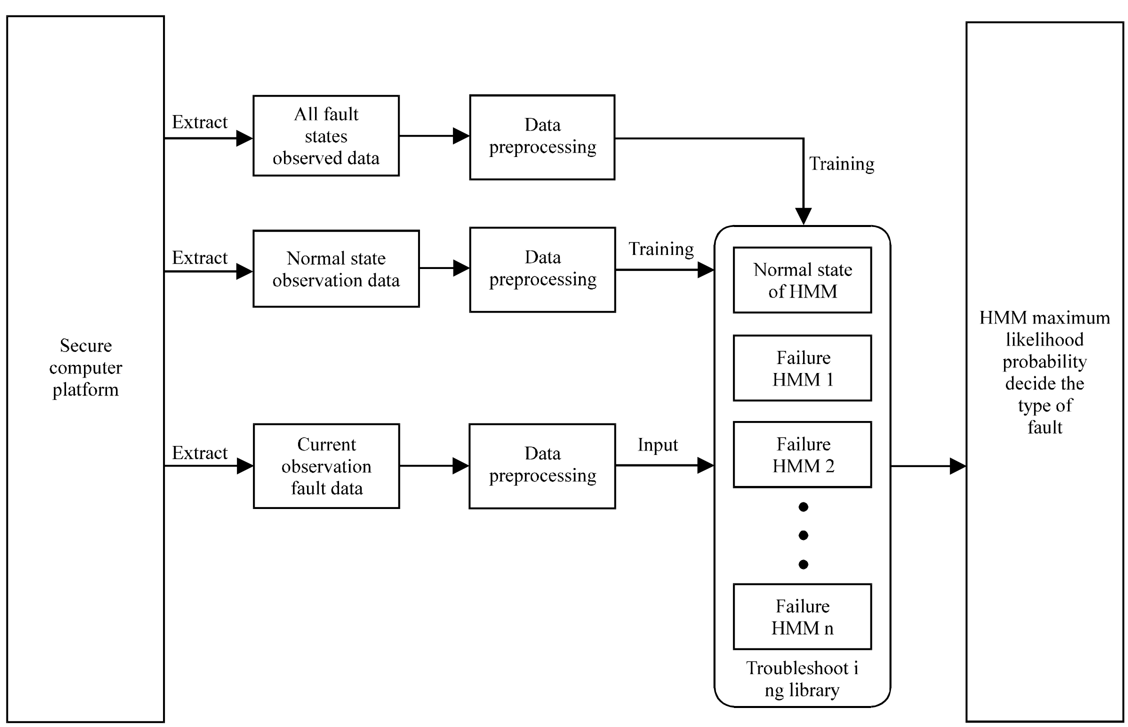

Fig. 2: Flow chart of fault diagnosis based on HMM

FAILURE MODE OF SECURITY COMPUTER SIMULATION PLATFORM

Select the type of fault: Under the circumstances, as appropriate, repair, fail-safe computer platforms are often an early stage of system failure has not yet expired, the majority of uncertainty which is dominated by the complexity, limitations and diagnostic testing means failure characteristics faint objects of the decision. In addition, due to the security of computer platforms wide range of component elements, uncertain information during flooding, the performance of complex fault(Spitzer and Xie, 2010).Under the external security of computer platforms and fewer checkpoints, the fault feature more likely to exhibit the characteristics of uncertainty and not complete. Therefore, the focus of fault diagnosis fault location can not be a single component, but should be studied for safety troubleshooting computer platform relatively large functional modules. With the modular design of computer security platform and higher levels of integration technology, the module level fault diagnosis system is also becoming increasingly important. So for the security of computer platform module level fault diagnosis is necessary.

Complexity of the system hardware configuration, fault diagnosis also determines the need for computer security platform with the "soft" failure to carry out research.

The various modules secure computer platform communicate with each other via the switch. In the system working process, inevitably affected by a variety of external interference signals, these interfering signals will affect the normal communication between the modules. Due to the security requirements of real-time computer platform, the system time factor, there are strict requirements, so when the interference signal is strong enough, it will destroy the relationship between dual synchronous computer security platform.In order to study the security of Fault Diagnosis of computer platforms,Here applying random interference fault interference signal, analog systems to secure computer platform simulation modules through the interference source.

Simulation of fault state: Fault diagnosis for computer security platform is in the system status monitoring, to determine the health of the lower system in offline circumstances.

In order to simulate the communication platform outside interference and is about to lead to dual-step. First, the micro-cycle test the security of computer simulation platform to work when the time runs of ($T_0 1$, $T_0 2$, $T_0 3$) suitably extended to ($T_1 1$, $T_1 2$, $T_1 3$), where $T_0 1<T_1 1$, $T_0 2<T_1 2$, $T_0 3<T_1 3$, Set up ($T_0 1$, $T_0 2$, $T_0 3$) for the health assessment threshold point, Let ($T_1 1$, $T_1 2$, $T_1 3$) micro-cycle timing time to work for the security of computer simulation platform normally that is, functional point of failure. Use the fourth general-purpose computer for analog sources of interference, In VC6.0 compiler environment, using a connectionless protocol (such as UDP), achieve socket communication, transmission frequency and length of the random interference signal to the security of computer simulation platform, Fig. 3 is a simulation software flow interference source module. Assuming the actual consumption of micro-cycle time (t1, t2, t3), When meet $T_0 1<t1<T_1 1$ or $T_0 2<t2<T_1 2$ or $T_0 3<t3<T_1 3$, explain the interference signal is about to lead the security of computer simulation platform dual-step that is consistent with the maintenance of conditions, as appropriate. At this point the actual extraction of micro-cycle consumption of time (t1, t2, t3) as the sample data fault state. Computer simulation platform safety case does not occur functional failures, system failures determine flow chart shown in Fig. 4.

In the course of the simulation work properly of the secure computer platform, FTSM need to extract the data input micro-cycles, FTSM need to extract the data input micro cycle, the actual time-consuming application of ZC micro cycle, the data output of the micro-cycle and at the end of each work cycle, it is judged whether the extracted data satisfies $T_0 1<t1<T_1 1$ or $T_0 2<t2<T_1 2$, or $T_0 3<t3<T_1 3$.If not, indicating that the interference did not make a computer simulation platform security failures, Discarding the extracted data (t1, t2, t3);If so, explain the health security of computer simulation platform has reached the maintenance of conditions, as appropriate, (t1, t2, t3) need to save for fault diagnosis.

FAULT DIAGNOSIS BASED HMM SECURE COMPUTER PLATFORM

Troubleshooting data extraction: Select the security of computer simulation platform for the normal-state mode, PU1 cause a system failure due to the interference pattern, FTSM cause the system to malfunction due to interference pattern, CC lead to system failure due to the interference pattern, the entire computer simulation platform safety system failure mode due to interference caused five states mode.

As shown in Fig. 3 and Figure Section 2-3, Sources of interference were sent to PU1, FTSM, CC, the entire system interference signal, extract the active fault state sample data. using a common source of interference PC

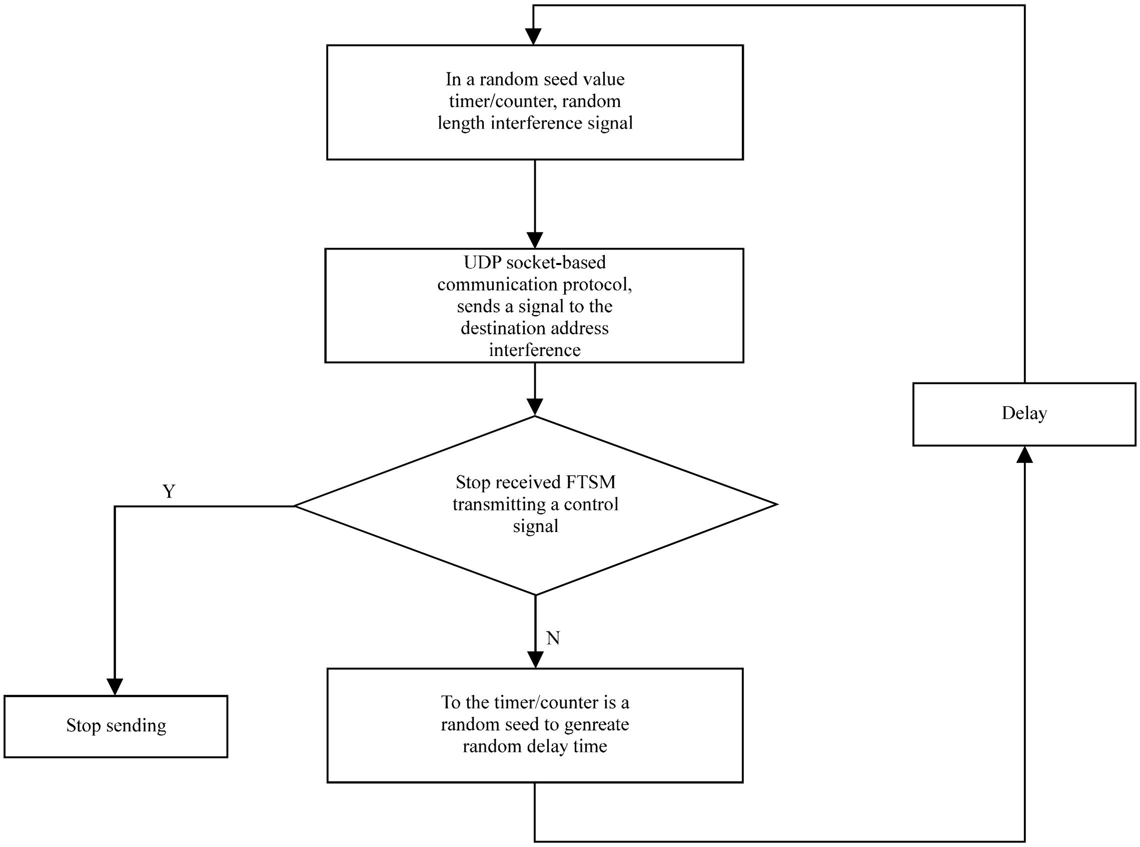

Fig. 3: Flow chart of simulation interference source

Table 1: Sample data extraction and pretreatment process of fault diagnosis

Failure mode	Interfering signals	Role of the target address	No. of data sample group (3-D)	Sample data (ticks)	LDA after treatment
Normal state mode	-	-	1000	(367, 375, 192), (365, 377, 190)	492.83, 497.59
PUI failure mode interference	Frequency length of random	192.168.0.100	1000	(517, 465, 306), (518, 435, 278)	680.69, 655.44
FTSM failure mode interference	Frequency length of random	192.168.0.102	1000	(516, 470, 281), (485, 466, 281)	659.01, 645.51
CC failure mode interference	Frequency length of random	192.168.0.102	1000	(449, 432, 279), (450, 438, 278)	646.72, 627.25
System failure interference	Frequency length of random	192.168.0.255	1000	(512, 445, 277), (516, 465, 278)	684.1, 656.46

simulation shown in Fig. 5, In VC6.0 compiler environment, the use of socket communication to send a signal to the random interference of each module (assuming each unit module is connected through the switch's address is: PU1: 192.168.0.100, PU2: 192.168.0.101, FTSM or CC: 192.168.0.102) unit system. Security computer simulation platform, the use of a general purpose computer to achieve FTSM and CC functions, so it is necessary to send the source of interference to the general computer work interfering signals at different moments tasks were simulated FTSM, CC failure modes. Broadcast (broadcast address 192.168.0.255) way interfering signal is applied to the entire system, the entire system can be extracted sample data due to interference resulting in failure.Sending the extracted sample data to a computer malfunction state module specifically for data acquisition and processing, for subsequent data processing.

Troubleshooting data preprocessing: Five models were extracted sample data 1000 groups, each group is a three-dimensional array, using the LDA method to reduce the dimension. Troubleshooting specific sample data extraction and pre-processing as shown in Table 1.

Troubleshooting training library: As in the previous chapter, the state security computer simulation platform is divided into four categories (Liu and Zhang, 2007):

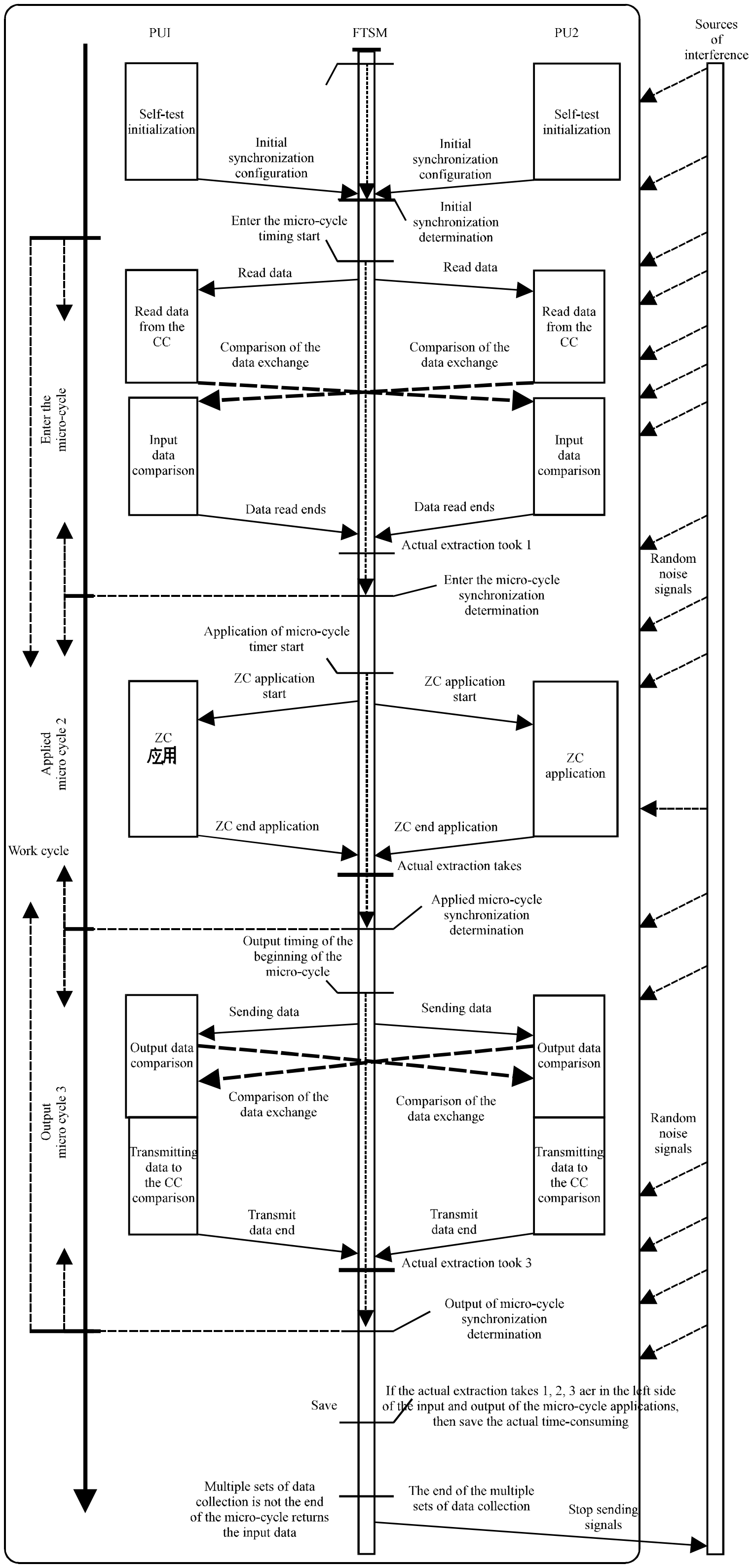

Fig. 4: Flow chart of simulation platform interference fault judgement

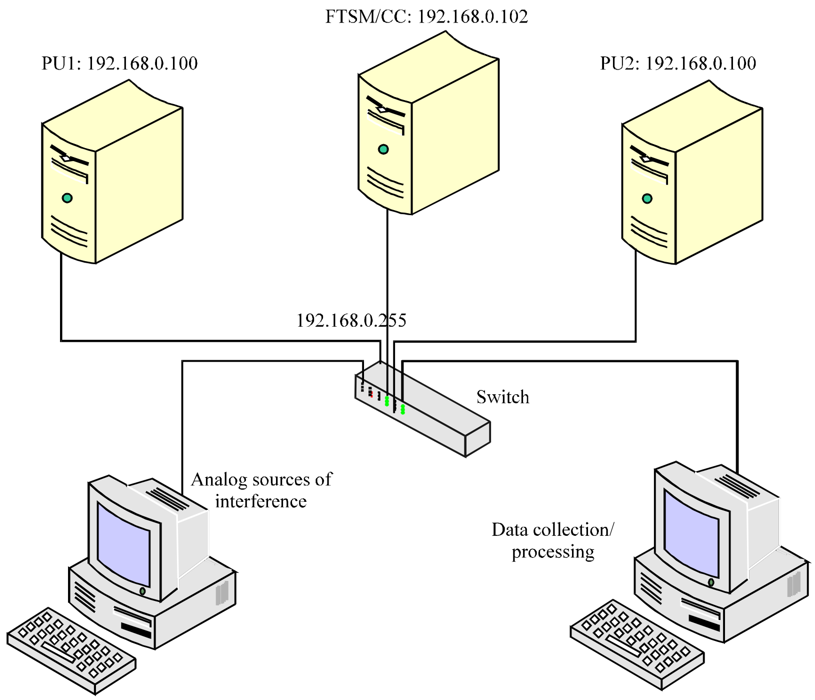

Fig. 5: Model of fault diagnosis data extraction

Normal state (0), weak fault state (1), intermediate fault state (2) and the complete failure of state (3),that is, N = 4. The initial probability distribution of $\pi = [1, 0, 0, 0]$. The initial state is the normal state of the moment.The probability of the next time and the current state of the system is transferred to the next state is equal, That is the state transition matrix is:

$$A = \begin{bmatrix} 0.5 & 0.5 & 0 & 0 \\ 0 & 0.5 & 0.5 & 0 \\ 0 & 0 & 0.5 & 0.5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Select 1×10^{-4} HMM training as convergence condition that is, when the output is similar to the probability of change is less than 1×10^{-4}, training terminated (Cong and Wang, 2004).

Respectively, the normal-state mode, PU1 cause the system to malfunction due to interference pattern, FTSM cause the system to malfunction due to interference pattern, CC lead to system failure due to the interference pattern, the entire security computer simulation platform for the group due to interference resulting in 1000 after LDA(Cong and Wang, 2004) observational data processing system failure modes, constitute a sequence of 100 sets of observations, each 10 observations. Each

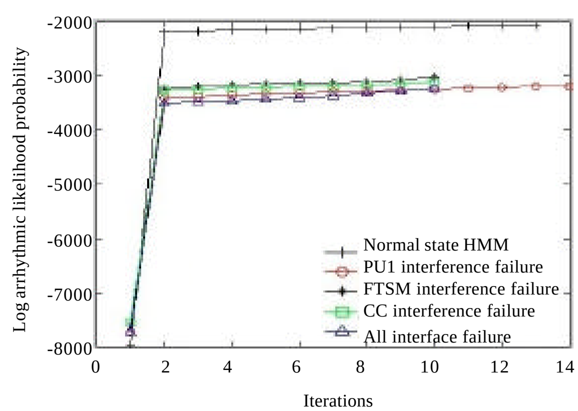

Fig. 6: Training curves of five kinds of HMM modes

mode, randomly selected 50 sets of observations HMM training sequence, the other 50 sets of observations for troubleshooting test sequence.

Sample data for each mode, after several iterations, will get a sample of data is most consistent with that $P(O|\lambda)$ the biggest HMM, Training process shown in Fig. 6.

The last five modes of training models to achieve convergence conditions, training to obtain the corresponding HMM. Normal state mode after 13 iterations required training, PU1 cause the system to malfunction due to interference patterns after 14 iterations required training, FTSM cause the system to malfunction due to interference pattern, CC lead to system failures due to the interference pattern and the entire computer simulation platform safety system failure due to interference caused after 10 iterations mode requires training. HMM five modes constitute a fault diagnosis library that provides the basis for subsequent model fault location.

Results of fault diagnosis system: After troubleshooting the library computer simulation platform for the establishment of security, you can use the method shown in Fig. 2-1, conduct the fault diagnostic tests.

The other 50 were taken in five sets of observations sequence mode, as the test sample, conduct the fault diagnostic tests. The following five modes, respectively,

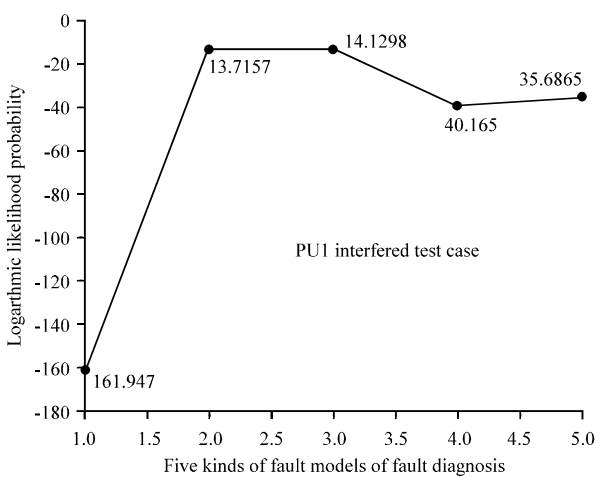

Fig. 7: HMM likelihood probability between PU1 undisturbed sample data and fault diagnosis database

five times the fault diagnostic tests, each test 10 randomly selected set of observations is not repeated sequence of each mode. Figure 7 shows the time in which a disturbance will cause the test results PU1 of 10 groups after observing sequence input to the system failure troubleshooting library, After averaging the results obtained.

The results show, PU1 interference caused by the sample input data to the number of system failure mode for the normal state of the HMM likelihood probability is obtained -161.947, PU1 is input to the interference caused by the number of failure modes of the system obtained in the HMM likelihood probability -13.7157, FTSM (Liu, 2006) due to noise input to the system the number of failure modes in the HMM likelihood probability is obtained -14.1298, the number of inputs to the CC system failure due to interference patterns obtained in the HMM likelihood probability is -40.165 input to the simulation number of computer security platforms cause a system failure due to interference pattern obtained HMM likelihood probability is -35.6865(Liu, 2006). Because the number of sample data is input to the interference caused by system failure PU1 pattern obtained HMM maximum likelihood probability, it is considered that the extraction of the sample data, the failure mode in which the system is processing unit PU1 system malfunction caused by interference.

The list of all the test results are are presented Table 2-6 (After averaging).

The test results, except for a few troubleshooting errors, most tests can be carried out correctly classified and therefore the security of computer platforms using HMM for fault diagnosis has a good diagnostic results. Table 7 shows the five simulated conditions, respectively, 50 times the statistical results of fault diagnosis which is not repeated randomly selected for each mode of a set of observations for each test sequence.

Table 2: Logarithm likelihood probability and diagnosis of the normal mode based on the five kinds of HMM modes (5 times)

Test code	Normal state HMM	PU1 interference HMM	FTSM interference HMM	CC interference HMM	HMM interference entire simulation platform	Diagnostic results
1	-14.4961	-60.5661	-76.8922	-31.0505	-67.9741	Normal system
2	-14.3117	-60.9925	-76.2226	-31.2658	-68.9635	Normal system
3	-13.9874	-61.8763	-73.5841	-31.6965	-64.0394	Normal system
4	-14.6522	-61.2382	-75.3960	-31.8889	-67.5642	Normal system
5	-13.9097	-60.9562	-76.0029	-31.5625	-67.5691	Normal system

Table 3: Logarithm likelihood probability and diagnosis of PU1 interference fault mode based on the five kinds of HMM modes (5 times)

Test code	Normal state HMM	PU1 interference HMM	FTSM interference HMM	CC interference HMM	HMM interference entire simulation platform	Diagnostic results
1	-161.9470	-13.7157	-14.1298	-40.1650	-35.6865	PUI interface fault
2	-161.5896	-14.9966	-16.2562	-41.2388	-39.9562	PUI interface fault
3	-166.1258	-13.3625	-16.3294	-40.0039	-34.0258	PUI interface fault
4	-161.0394	-15.9562	-15.9125	-39.9520	-39.6952	PUI interface fault
5	-161.6582	-14.0702	-14.9801	-43.9992	-35.0204	PUI interface fault

Table 4: Logarithm likelihood probability and diagnosis of FTSM interference fault mode based on the five kinds of HMM modes (5 times)

Test code	Normal state HMM	PU1 interference HMM	FTSM interference HMM	CC interference HMM	HMM interference entire simulation platform	Diagnostic results
1	-147.9562	-14.9747	-14.4961	-36.5555	-31.3332	FTSM interface fault
2	-151.0910	-15.9225	-14.2206	-36.5117	-31.8988	FTSM interface fault
3	-150.3691	-14.2900	-14.5966	-36.7117	-31.0070	FTSM interface fault
4	-152.0090	-14.6995	-14.9954	-33.0701	-30.0995	FTSM interface fault
5	-149.8577	-14.6594	-14.6582	-34.2599	-30.4752	FTSM interface fault

Table 5: Logarithm likelihood probability and diagnosis of CC interference fault mode based on the five kinds of HMM modes (5 times)

Test code	Normal state HMM	PU1 interference HMM	FTSM interference HMM	CC interference HMM	HMM interference entire simulation platform	Diagnostic results
1	-026.0403	-55.2322	-59.4991	-14.4961	-77.0945	CC interference fault
2	-26.8877	-55.0040	-54.3332	-14.3932	-70.552	CC interference fault
3	-29.4999	-57.0698	-57.0000	-14.5582	-74.6662	CC interference fault
4	-27.6778	-57.7447	-57.9006	-13.9474	-74.554	CC interference fault
5	-27.4755	-60.0888	-55.3346	-14.7447	-75.004	CC interference fault

Table 6: Logarithm likelihood probability and diagnosis of the whole system interference fault mode based on the five kinds of HMM modes (5 times)

Test code	Normal state HMM	PU1 interference HMM	FTSM interference HMM	CC interference HMM	HMM interference entire simulation platform	Diagnostic results
1	-107.2991	-29.6604	-19.1100	-54.7440	-19.4705	FTSM interference fault
2	-107.0004	-32.6541	-22.3603	-55.9772	-17.3269	Disturbed the whole system failure
3	-104.5673	-33.0303	-20.9015	-54.5976	-17.9674	Disturbed the whole system failure
4	-106.5540	-31.9472	-20.7404	-55.3661	-19.6692	Disturbed the whole system failure
5	-106.0440	-35.3005	-19.4219	-54.3397	-19.2200	Disturbed the whole system failure

Table 7: Statistical fault diagnosis results based on five kinds of HMM modes (50 times)

Determine the type/ original class type	Positive often state	PUI therefore barrier state	FTMS therefore barrier state	CC therefore barrier state	Fault simulation platrorm entire state interference	Knowledge other rate (%)
50 times the normal mode	50	0	0	0	0	100.0
50 PUI failure mode	0	44	5	0	1	88.0
50 FTSM failure mode	0	11	36	1	2	72.0
50 CC failure mode	3	0	0	47	0	94.0
50 system failure mode	0	1	3	0	46	92.0
Average recognition rate						98.2

Can be drawn from Table 7, the security of computer simulation platform for the entire system or module interference caused by system failures, HMM fault recognition rate of over 89%, with the algorithm is stable, training speed, high precision classification.

CONCLUSION

Here, provides in-depth research on fault diagnosis technology security HMM-based computer platform; the research is interference fault location systems. On the basis of the previous chapter, the chapter first discusses the HMM used in fault diagnosis system advantages in the application process to study the HMM system fault diagnosis and then implement each module of the system simulation using simulation computer platform security disturbance and cause system failure and finally a detailed study of the process of troubleshooting computer security platform. The whole process includes extracting the normal state and the original sample data for each fault state micro cycle training LDA pretreatment, restructuring time series databases and fault diagnosis system for fault diagnosis decision analysis.

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