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Vibration faults detection using wireless and neural network

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Abstract

The maintenance cost is the main challenge of the industrial environment especially that related to the expansive machine. Many faults caused damage to the machine as the oil flow, pressure, vibration, and temperature. The vibration fault of the rotating machine is producing damage if been in the danger zone. In this work, the vibration fault of the induction motor has been detected and classified based on wireless and artificial intelligence techniques. The C++ code was utilized to design and implement the wireless sensor, while the MATLAB code was used for the constructed artificial intelligent part. The results showed that the vibration error can be detected early if the beam length is reduced in the wireless sensor. The system was designed based on utilizing the wireless sensor (sensor of vibration, microprocessor, Zig Bee), while the second part contained the coordinator to collect data from the wireless sensor and the cod for processing and analyzing data within a computer. The method proposed in this work shows that the processing time required to collect and analyze vibration data is 2.63 seconds, which is less than the processing time in other methods. The system can be used with other types of machines based on the training of new neural networks to obtain new information to reduce detection time and classification.

Keywords: *Vibration faults detection, faults detection methods, wireless sensor networks, neural network.*

1. Introduction

Vibration physical phenomena are generated due to the cracks, imbalance, or uneven friction of the rotating part. Also, it generated on static things such as buildings, and bridges. Vibration is not desirable, as it wastes energy and creates unwanted sounds. Dynamic vibration generated in motors, engines, or any mechanical device in operation is usually undesirable. Thus, this fault caused a high cost to maintain the machine if got damage which is resulted from the vibration. Careful designs usually minimize unwanted vibrations and suggest new schemes to detect and process vibration fault [1].

Fault detection (FD) is a technique concerned with monitoring faults system, identifying when a fault has occurred and pinpointing the type of fault and its location. Two stages that can be used to distinguish vibration faults are direct recognition of the pattern of sensor readings that indicate an error and analysis of the discrepancy between sensor readings and expected values based on AI technology. While the data collected via a central computer for analysis, detection, and decision-making to protect the device from damage if it is at a risk level, represents the second approach. These techniques isolate and classify the fault level and location in the machine[2].

There are many methods proposed for fault detection to diagnosis the fault that occurred in an industrial machine such as vibration, pressure, flow, and temperature. The value of these faults will be caused damage if been at the danger level. Mostly, fault classification is at a normal, alarmed, and dangerous level. Methods that take care of the fault detection are an artificial neural network, fuzzy logic, support vector machine, and the wavelet [3]. the utilization of these methods is depending on the signal complexity and real-time processing such as noise, vibration, and pressure [4] [5].

Recently, researchers are hybrid multi-technique to enhance the decision precision of the fault diagnosis on machines. Moreover, reducing the cost of installing the system in the harsh environment pushes the use of wireless sensors, information cloud, and the Internet[6]. Other researchers used ne method to detect the vibration signal such as [7] where the FFT technique is used. In [8] the researchers used the wavelet technique while the SVM used in the [9]. The main aim of the researchers in [10] [11] was to protect the machines from damage and proposed scheme that preventing the fault been in danger level based on the wired or wireless technique. This section will mention some works related to condition monitoring which is utilized in different schemes. SVM is used to classify and detect a fault [12]. In [13] the fuzzy is utilized to classify the vibration fault on the steam turbine based on the simulation of the vibration signal that greeted the machine. While in [14] utilized a multi- neural network for fault classification and identify the number of the bearing in the gas turbine that got a fault, (the research interested in the gas turbine). In [15] implemented a wireless vibration sensor to detect the vibration signal in law frequency that is generated on the expansive machine. In [16] approached system to diagnosis the vibration based on the neural and wireless technique, the main objective of this paper is to enhance the power consumption of the wireless sensor processing. In [17] approached design wireless system for vibration fault detection on the induction motor. The research used the wireless technique, neural, and fuzzy for improving the decision precision. The main aim of this paper is to enhance the time processing and fault detection scheme based on the utilized new methodology that hybrid the wireless and artificial intelligence techniques to protect the machine. The methodology is based on the condition monitoring of vibration faults.

2. Methodology

This work was designed in two stages, firstly: implement and design the wireless sensor network that includes the router, coordinator, and end node. Secondly: collecting data from the wireless sensor by the computer during real-time processing as shown in Figure 1. The data was analyzed for detection and classification of the fault level. The test bed is an electric motor and the imbalance load was used in the work as shown in Figure 2.

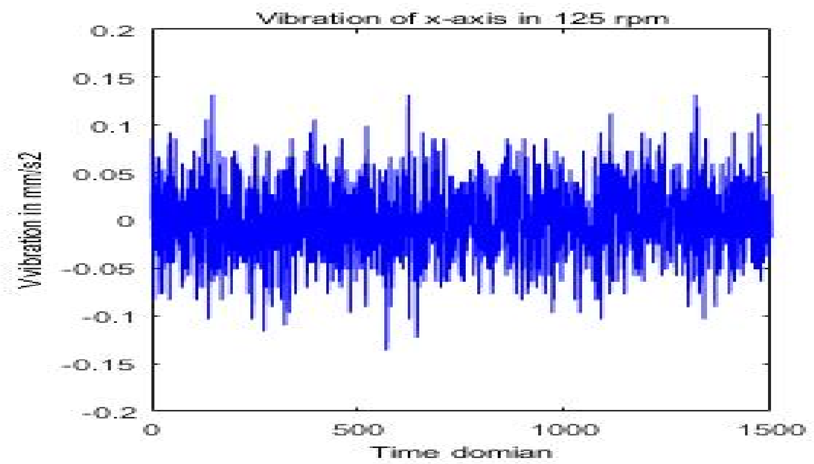


Fig. 1: The raw vibration fault data.

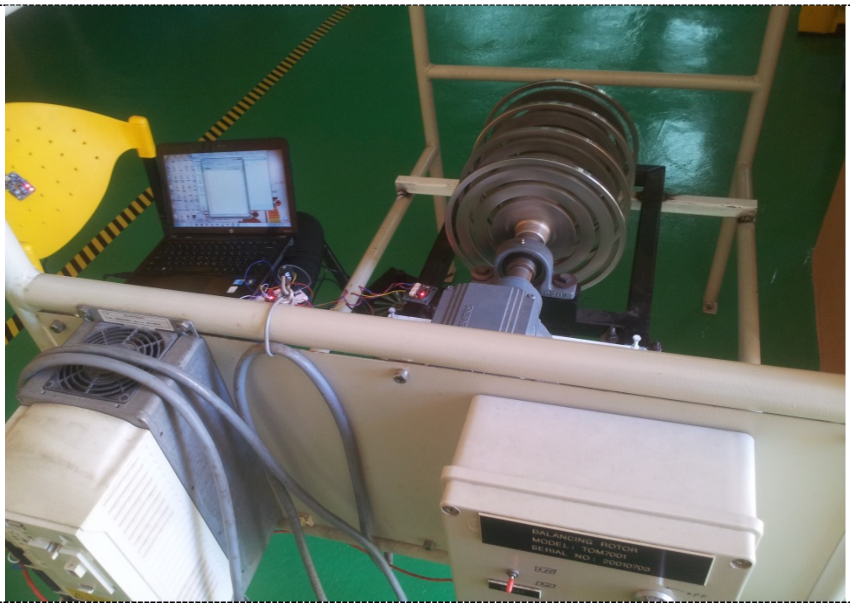


Fig. 2: Data collected from test bed.

3. System framework

The framework of the system design consists of wireless network that represents the collections stage, signal processing, and a neural network that represents the analysis stage, while the monitoring and classification stage showed as a smart stage for displaying the fault level.

3.1. Wireless Stage

This stage consists of two types of sensors, the wireless speed sensor, and the vibration wireless sensor. The two sensors are similar in most parameters but different in the physical part only. Where, the speed sensor utilized a sensor for detecting the pulse width of the rotating speed of the motor shaft, while the vibration sensor utilized the acceleration sensor. Moreover, each sensor contained the power supply, microcontroller ATmega 328, and the Wi-Fi stage represented by ZigBee. The speed data will collect and send to the vibration sensor and then the data of the speed and the acceleration will send to the router that was connected to the computer as shown in Figure 2. These data contained the speed and vibration fault value in the one packed will sprat and processing in the next stage

3.2. Analysis and Processing Stage

The data that was collected by the computer based on the MAT LAB code will be saved. These data contained the speed and vibration faults. Thus, will be separated to process the vibration data. Fig.1 showed the raw data of the vibration-contained noise represented by the harmonic frequency and noise. Therefore, the signal should be processed using the low pass filter and the band filter to get a signal without harmonic frequency and show the resonant frequency that is related to the speed value of the motor. The filtering signal will be sent to identify and classify the fault by using the neural network. The output of the filter stage will give a signal without noise as shown in Figure 3 which contains the signal filtered related to 125 rmp.

The back propagation error neural network (BPNN) is one scheme of the neural network application. It was used to identify the fault in this work. The BPNN was trained by the data which represent the fault in different resonant speeds. Thus, the training will stop after the output error reaches the required value. And resulting data from the training will save in the computer and utilizing with online fault detection to compare the new input signal with the saved signal for fault detection and classification.

3.3. Decision Stage

This stage depends on the data result of the neural network. This stage analyses the fault based on the speed of the machine. In normal cases, the rotating machines have a high vibration value at a critical speed. Thus, the vibration fault in the critical speed is of high value but is not represent the fault case. Based on this situation, if the neural network discovers the vibration and the speed is a critical value, the system ignores that fault. While if the fault is identified by a neural network and the speed in normal case that will produce a signal representing the value of the fault and show to the operator the vibration fault in alarm or danger level based on the fault level generated on the machine.

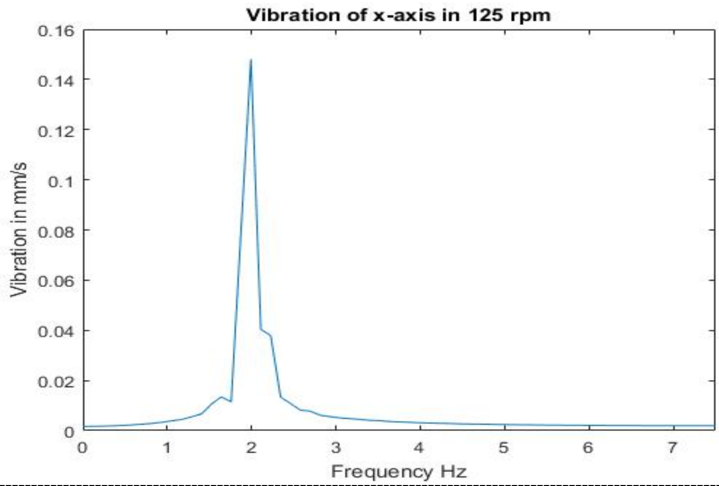
4. Results of the work

4.1. Data collection

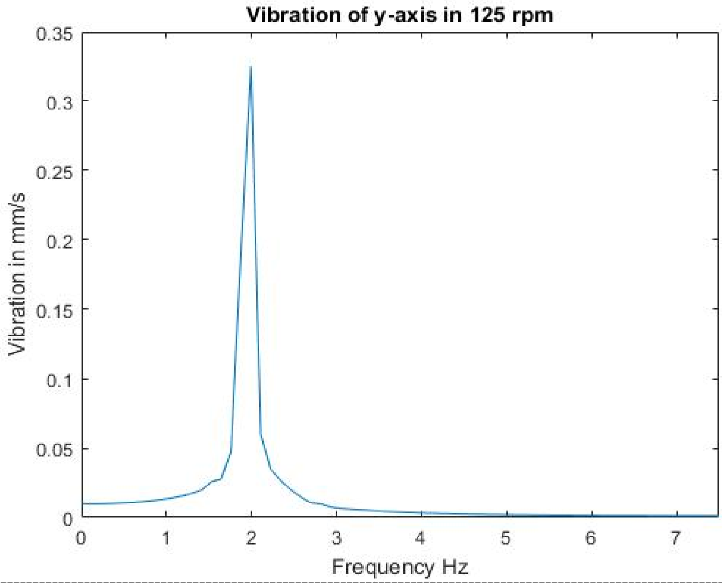
The data was collected successfully from the wireless network and saved inside the computer for analysis as shown in Figure 3. The data of the speed and vibration fault gather as 256 bytes. The packet contained is arranged as: the first byte represents the speed value, and the following three bytes represent the acceleration as X, Y, Z axis. The time needed for collecting data is (2.63s) for 256 bytes. The speed and acceleration data are sent from the wireless sensor as capsulate values to reduce the packet size, where the process will reduce the collection time of the information. Thus, the vibration fault will discover in a better time to avoid damage to the machine.

4.2. Data analysis

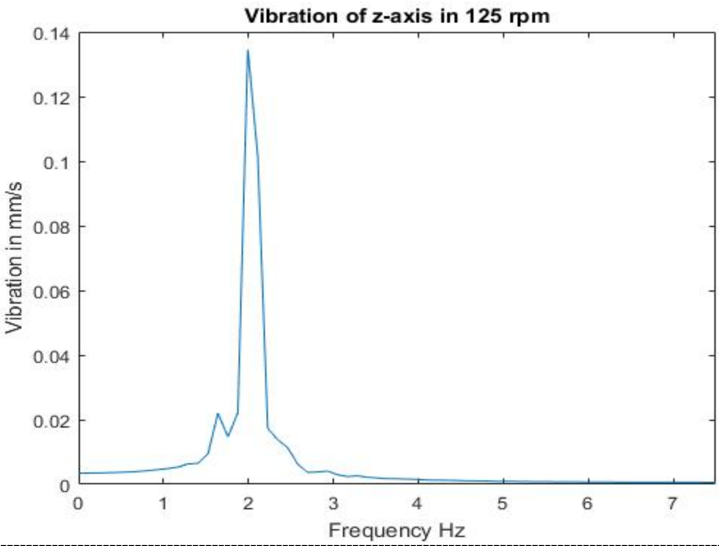
The result of the signal processing stage showed that the design has successfully filtered the noise from the raw signal. The LPF removed unwanted signal and frequency, while the BPF is identifying the signal in the resonant frequency of the machine. Two speeds were selected in this work, the first speed is 125 rpm, and the second speed is 175 rpm. The result of the BPF monitored signal in two frequencies (two speeds selected) that mean filter identifies the resonant frequency automatically. The output of the filtering will feed online to the NN stage of the process to compare the incoming signal with the saved signal. The resulting training of the NN for the two speeds 125, and 175 rpm is shown in Figures (4 and 5) respectively. Also, the value of the error produced from the training of the NN proves that the system will discover the fault with high accuracy in the real-time scheme as shown in Figure 6.



(a)

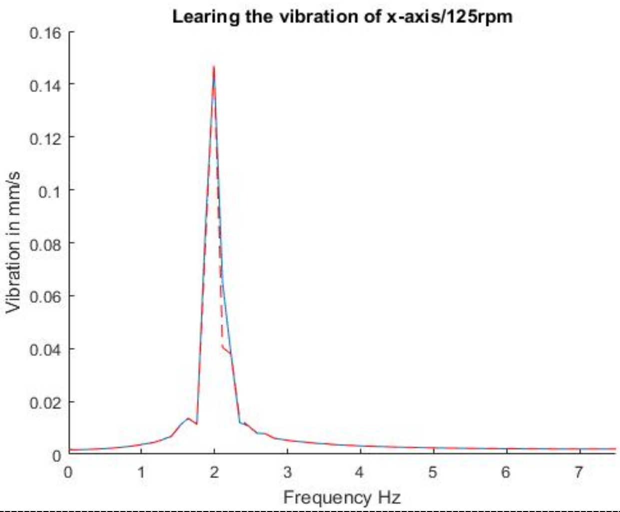


(b)

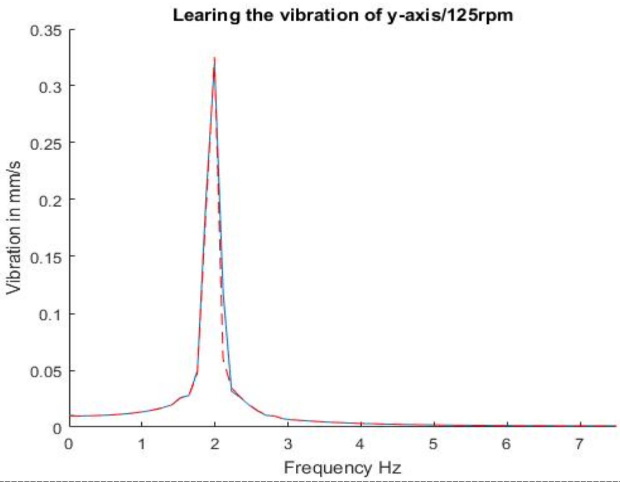


(c)

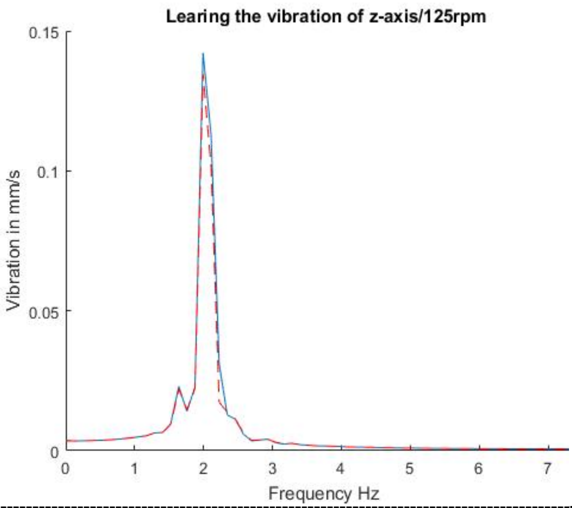
Fig. 3: Result of the single processing stage for 125 rpm (a)x-axis (b) y-axis (c) z-axis



(a)

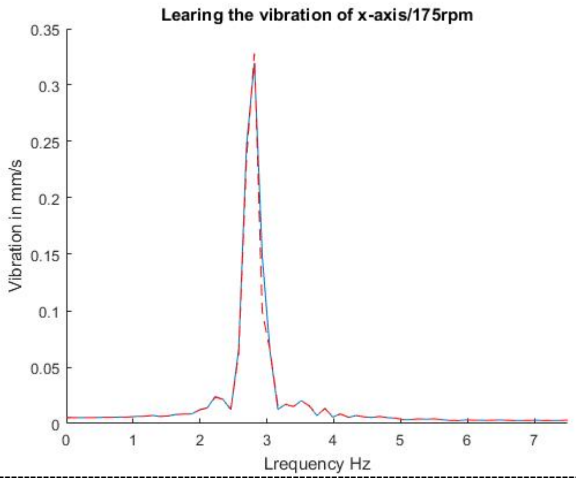


(b)

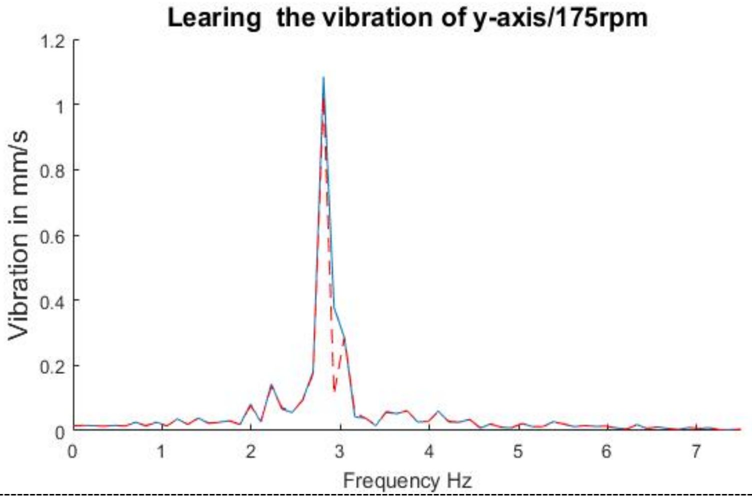


(c)

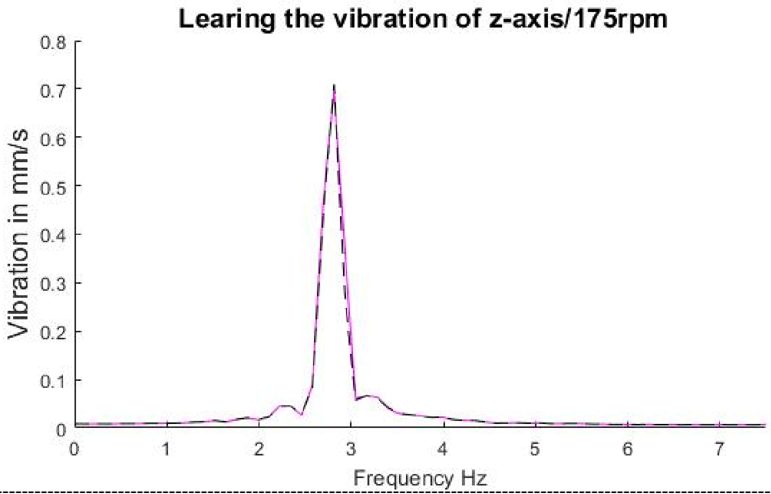
Fig. 4: Result of the NN training for 125 rpm (a)x-axis (b) y-axis (c) z-axis



(a)

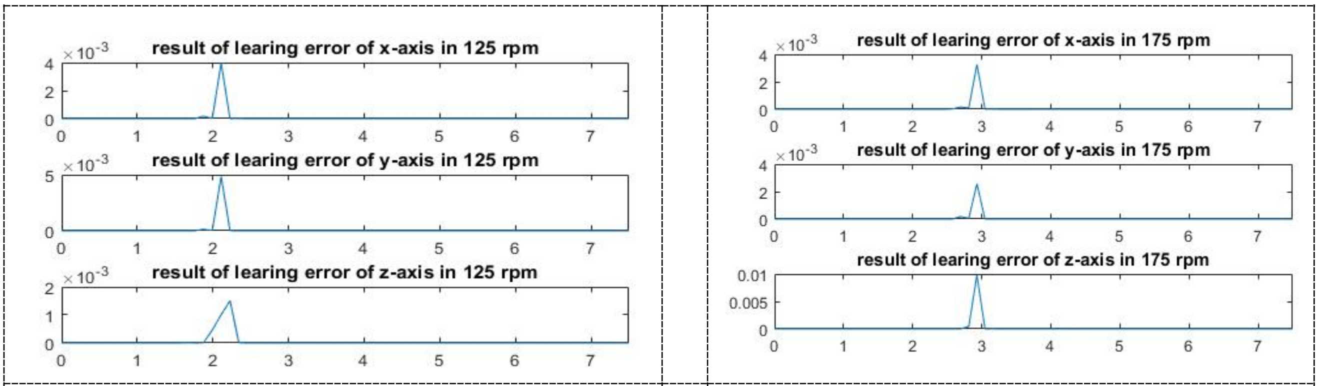


(b)



(c)

Fig. 5: Result of the NN training for 175 rpm (a)x-axis (b) y-axis (c) z-axis



(a) **(b)**

Fig. 6: Error resulted from NN training for (a) 125 rpm (b)175 rpm.

4.3. Carry out decision

The smart scheme was designed in the MATLAB code, which is depending on the speed value and the fault decision. In this part, the decision will depend on the speed value because the critical speed values were identified in the code. Thus, the system will ignore the fault if the machine is within critical speeds. However, the vibration fault is discovered via NN, and it is at a high level. On another side, the system will take action to alarm the operator if the vibration is at a high level and the machine speed is in a normal situation, Table 1 below show the time scheme of the system. Figures 4, and 5, show that the vibration increases if the speed of the machine is increased Table 1 illustrates that the testing time for collecting and processing 256 samples is 2.

Table 1: Time scheme of system during real time processing

Samples RPM, x,y,z	Time to collected via MATLAB (s)	Neural Online processing (s)	Training time (s)	Computer bud rate	Samples/time (Sampling rate)	Sensor convenient
256	2.63	0.083	0.88	19200	88	0 ~40 Hz

5. Conclusion

The system was designed to identify and classify the vibration fault of the induction motor based on artificial intelligence and wireless technology. The designed system discovers the fault early based on collecting the vibration fault with three axes. The processing time required to collect and analyse vibration data is 2.63 seconds. The testing time for collecting and processing 256 samples takes 2.63sec, while the testing time of 512 samples for the same processing is 5.03s. Based on the results of this work, selected the first case for fault detection. The time of processing was improved if compared with other works. Moreover, this work discovers the fault by the analysis of raw vibration data, if the vibration fault increase in the y-axis wills effectively more than other axes. Thus, future work suggests designing a system that depends on collecting the y-axis only to identify the fault of vibration. The real-time of the system will reduce if collecting one axis only, which will lead to enhanced system protection

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