Research and Realization of Vehicle Fault Diagnosis System based on Cloud Computing

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Abstract. This article through to the analysis of the traditional vehicle fault diagnosis instrument, and research the related theory and characteristics of cloud computing and related core technology, put forward the vehicle fault diagnosis instrument based on cloud computing, it will store all the data in the cloud that the fault diagnosis required for, and do a big data parallel computing in the cloud. In order to improve the accuracy of fault diagnosis, the realization of the BP neural network in the graphs under the writing model of Map Reduce is achieved. Through on the test platform of validation showed that the vehicle fault diagnosis based on cloud computing can accurately diagnose the car trouble, compared with others vehicle fault diagnosis apparatus, the design has characters of handle huge amounts of data, cheaper investment of equipment and easier system upgrades, etc.

Keywords: Cloud Computing, Fault Diagnostic, Android, Map Reduce, Back Propagation.

1. Introduction

ECU (Electronic Control Unit) has been widely used in vehicle Electronic Control because of its excellent performance , on some luxury cars, the use of single chip microcomputer has more than 50, the number of Electronic products accounted for 70% of the whole vehicle cost, the amount of memory has gone beyond the dosage of the Apollo spacecraft three times[1].The development of vehicle electronic technology greatly promoted the comfort, safety, durability and sustainability spare parts supply of modern automobile, it makes car is not just a walking tool, but also the high-tech technology crystallization of information communication, intelligent driving, wireless remote control, image recognition and speech control.

Main function of vehicle fault diagnosis instrument is to read out the fault code and other information from the ECU, able to check out the car trouble preliminary, it improves the efficiency of maintenance and reliability of fault diagnosis. However, with the increase of car ownership, auto fault information will increase gradually, according to a report in the journal of the <Communications of the ACM>, unmanned vehicle will produce 1 GB of data to run every 1 seconds, so the troubleshooting way of traditional hand-held malfunction diagnosis or PC connected to the Internet through the server will not be able to satisfy the calculation of huge amounts of data.

2. The development and research status of the vehicle fault diagnosis

OBD-II performed more strict standard than OBD-I, partitioned the diagnosis pin number and the fault codes and the services unified. Due to the birth of OBD-II, the American Society of Vehicle Engineers (SAE) developed a set of standards, it required the automobile manufacturing provides unified diagnostic model by the standards of OBD-II, it provides a basis for research and development of commonality automobile fault diagnosis instrument. Vehicle fault diagnosis instrument at home and abroad mainly divided into two categories: hand-held vehicle fault diagnosis instrument based on microprocessor and remote auto malfunction diagnosis based on the server.

Hand-held vehicle fault diagnosis system based on "stand-alone" generally includes controller module, system memory, programming debugging/download circuit, power circuit, CAN communication circuit, external storage, such as SD card interface circuit, liquid crystal display circuit, keyboard/touch screen module[2].The system structure is shown in figure 1:

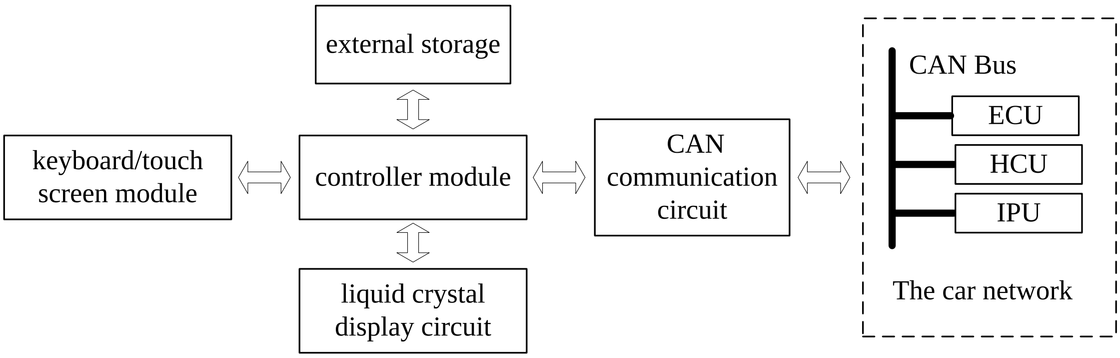

Fig. 1 Structure diagram of hand-held vehicle fault diagnosis system

Hand-held fault diagnosis instrument get an idea of design the software and hardware tied, can be customized hardware and software based on the requirements, to play to the function of hardware and software maximum, ensured the reliability of the vehicle fault diagnosis instrument. But the diagnostic instrument needs a data line to connected OBD nodes at work, thereby limiting the range of mobile workers, and the production cost of hardware is higher, the software upgrade is difficult, and it do not have intelligent diagnosis.

The remote fault diagnosis system based on “server + terminal software” can be divided into two kinds in accordance with the different control platform : vehicle fault diagnosis instrument based on PC and vehicle fault diagnosis instrument based on mobile terminals (such as mobile phone, tablet, etc.) of .They generally includes two parts: the fault diagnosis client and remote fault diagnosis center. Fault diagnosis client include: communication module, terminal (PC or mobile terminal), diagnostic software running on a terminal, remote diagnosis center include: diagnostic server, management server, data server, the expert client computer and experts, etc. Its system structure is shown in figure 2[3]:

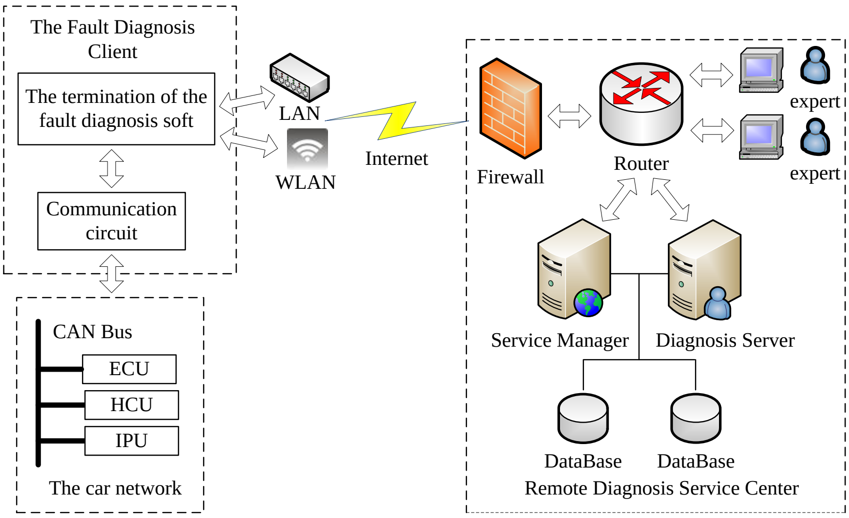

Fig. 2 The structure diagram of remote vehicle fault diagnosis system

The vehicle fault diagnosis system based on the remote service generally has the function of hand-held vehicle fault diagnosis system based on the "single", and strengthens the function of remote diagnosis service. Although the design to reduce the hardware investment and have remote diagnosis, the traditional server set up and maintenance requires a lot of infrastructure and professional, the traditional server does not have the ability to run huge amounts of data at the same time.

3. The realization of Back Propagation neural network in the cloud computing platform

3.1 The introduction of BP neural network

BP algorithm switch the input/output mapping problem of neural network learning into a nonlinear optimization problem [4].BP algorithm is made up of information forward-propagation and error back propagation .In the process of forward calculation, the input of information handled by input layer through the hidden layer to output layer, and each layer of neurons state affect the next state of neurons only. If the output layer didn't get the expected output, then turned to back propagation, the error signal return to the original passage .Three layer BP neural network structure as shown in figure 3:

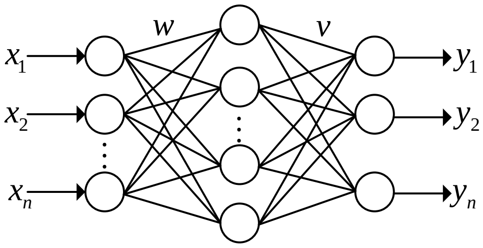

Fig. 3 The BP neural network structure

The learning process of BP neural network is under the stimulus of external input samples, in order to make the output of the network constantly close to the desired output, changing the network connection weights, .The essence of learning it is dynamic adjustment of the various connection weights, and the method of the rules weights adjustment is the gradient descent.

The output of the j th neurons is $y_j(n)$ in the n th iteration of the outputs, expect output is $d_j(n)$, then the error function for the neuron is

$$e_j(n) = d_j(n) - y_j(n) \tag{3.1}$$

Definition neurons j error squared is $e_j^2(n)/2$, then the output the total square error of the instantaneous value is

$$E(n) = \frac{1}{2}\sum_{j\in c} e_j^2(n) \tag{3.2}$$

c including all output unit, assume that a total of the training set samples is N, the mean value of error square is

$$E_{AV} = \frac{1}{2}\sum_{n=1}^{N} E(n) \tag{3.3}$$

E_{AV} Is a function of the ownership value, threshold value and the input signal? E_{AV} Is the objective function of study, the ultimate goal of learning is to make the minimum of E_{AV} .

3.2 The computational model

Define a three-layer neural network, to make the following calculation to each input sample.

(1) Forward calculate

j Of the l th layer neurons, the input is

$$v_j^{(l)} = \sum_{i=0}^{T} w_{ji}^{(l)} y_i^{l-1}(n) \tag{3.4}$$

$y_i^{l-1}(n)$ Is a working signal sent by the previous layer of neurons i, sigmoid function is the activation function of unit j, then?

$$y_j^{(l)}(n) = \frac{1}{1+\exp(-v_j^{(l)}(n))} \tag{3.5}$$

$$\varphi^{'}(v_j(n)) = \frac{\partial y_j^{(l)}(n)}{\partial v_j(n)} = \frac{\exp(-v_j(n))}{[1+\exp(-v_j(n))]^2} = y_j(n)[1-y_j(n)] \tag{3.6}$$

(2) reverse calculation partial derivative δ

The output neurons

$$\delta_j^{(l)}(n) = e_j^{(L)}(n) y_j^{(L)}(n)[1-y_j^{(L)}(n)] \tag{3.7}$$

The hidden neurons

$$\delta_j^{(i)} = y_j^{(l)}(n)[1-y_j^{(l)}(n)]\sum_k \delta_k^{(l+1)}(n) w_{kj}^{(l+1)}(n) \tag{3.8}$$

(3) The revised weight

$$w_{jk}^{(l)}(n+1) = w_{ji}^{(i)}(n) + \eta \delta_j^{(l)}(n) y_i^{l-1}(n) \tag{3.9}$$

Repeat (2) (3) steps, until the sample finish convergence.

Then command $n = n+1$, enter the new sample, repeated step (2) (3), until all the samples all convergence.

3.3 The introduction of Hadoop

Hadoop play a defining role in the distributed open source evolution framework of Apache open source organization, have been applied in many large sites, such as amazon, Facebook, Yahoo and so on. The core design of Hadoop framework is: Map Reduce and HDFS, this article mainly analysis Map Reduce.

Map Reduce is a software architecture puts forward by Google that for parallel computing of large-scale data sets (greater than 1 TB) .The Concept "Map" and "Reduce", and their main ideas is borrowed from functional programming language, and their features is borrowed from the vector programming language[5].

Core steps of Map Reduce framework mainly divided into two parts: Map and Reduce. When you submit a computing operations to Map Reduce framework, it will split the calculation work into a number of Map tasks firstly, then assigned them to different nodes, every Map task processing part of the input data, it will generate some intermediate files when the Map task is completed, these intermediate files as input data to Reduce task. Reduce task's main goal is to put the front several Map output together and output.

3.4 The parallelizing Map Reduce of the BP neural network

Map Reduce programming model highly abstract parallel computing that complex operation in the process of the large-scale cluster to the functions of Map and Reduce, because of the parallel programming model generally closely related to the operating system and underlying architecture, generality is not strong, it is a simple, clear and effective way. There is a basic requirements suitable for Map Reduce to deal with the data set (or task): data sets waiting to be processed can be decomposed into many small data sets, and each small data set can be parallel processing completely.

The core of calculation model is Map and Reduce, the user responsible for implementation these two functions, function is input <key, value> pairs into another or a group of < key, value > the output according to certain rules of mapping.

First step is data partitioning phase, this phase decompose sample training set files into key/value pairs(files, samples)in the command node, then sent to the distributed system in each data node machine to Map Reduce calculated according to certain data block size (the default 64 MB) .

(1) The Phase of Map

The Map class calls the map() function, identify input value and the desired output according to the network structure after accepting input key/value pair, and calculate the local gradient weight of the variable Δw generated by its back propagation of network weights of each connection w, generate forms such as $(key = w, value = \Delta w)$ temporary key/value pairs, the temporary key/value pair produced by each Map task will temporarily store in a local file. The combine () function to $(w, \Delta w)$ key/value pairs as input, and for local reduction operation, statistic all temporary value pairs by keys w.

(2) Phase of Reduce

Reduce class calls reduce () function, as the stage of $(key = w, value = \Delta w)$ for intermediate input, and Reduce it, and the specific process o as follows:

$$sun \leftarrow 0, count \leftarrow 0 \tag{3.10}$$

$$sun \leftarrow sun + value \tag{3.11}$$

$$count \leftarrow count + 1 \tag{3.12}$$

$$sun / count = \sum_{i=1}^{n} \Delta w / n \tag{3.13}$$

Output form such as the key-value pairs of $(key = w, value = \sum_{i=1}^{n} \Delta w / n)$ after each reduce task finish, sent back to the command node, job() function do a batch update to each of the neural network weights, two weight matrix between three-tier network is saved to the global variables configuration file in cloud computing platform system , the next Map Reduce task can be iterative invoke.

If the neural network weight change is very small after multiple Map Reduce task operated, the weight within the specified range of error, the network learning process can be finished, the trained neural network can be used to classify and prediction according to the input variables after training.

The general idea of decomposing algorithm is to train the network by use the error back propagation algorithm, iterative updating the weights of network continuously, until convergence all the samples (training error meet the requirements), distributed implementation is do a batch handle and get the average as local gradient back propagation to generating a local gradient change quantity for each connection weights of the network that when all samples trained.

4. The design of vehicle fault diagnosis software

4.1 The overall scheme of the system based on Android

The vehicle fault diagnosis system based on android platform is include running android mobile terminal and an Bluetooth CAN equipment with OBD interface, the overall scheme of this system as shown in figure 4.

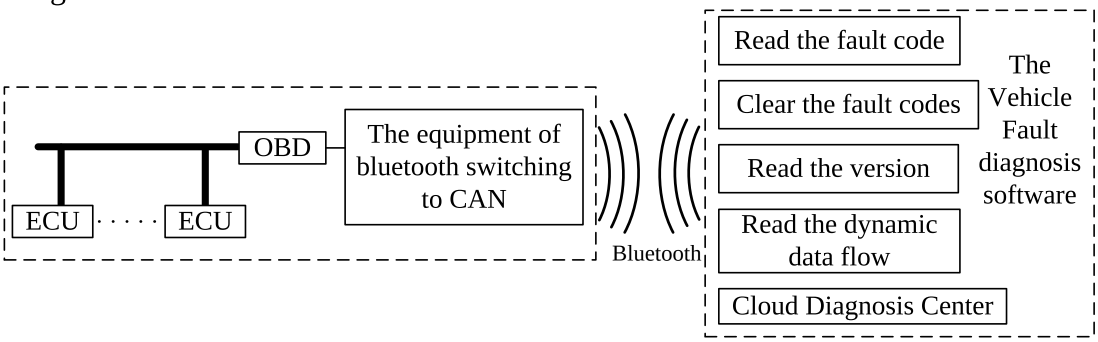

Fig.4 The overall scheme of the system

The vehicle fault diagnosis software includes an android mobile phone/tablet, a wireless communication with mobile phone/tablet and switch data that send by mobile phone/tablet of into a CAN message switching equipment (The equipment of Bluetooth switching to CAN). The equipment of Bluetooth switching to CAN includes: a Bluetooth communication module, a main controller, a CAN communication module. In diagnosis of cars, it need to make fault diagnosis software connect with cloud computing to get diagnosis instructions when the soft is diagnosing a car, transfer plate CAN interface CAN online access to the car at the same time. Transfer equipment working process is to use Bluetooth module and Bluetooth of mobile phone/tablet to realize communication; main controller transfer the data into a CAN message format and sent it to the car ECU via the CAN communication module when receiving the phone/tablet to send data, ;when the converting received data into a Bluetooth module communication message format will be sent via Bluetooth module to mobile phone/tablet when receiving the CAN message response of the car ECU , then phone/tablet send the data to the cloud computing platform through the network, the data could be deal with through the cloud computing platform.

Mainly functions of diagnostic instrument are: read the fault code, clear fault codes, read the dynamic data flow and version information, write VIN code, and other functions. Function of read the fault code is usually divided into read all fault codes, read history fault code and read the current fault code according to the requirements of manufacturers.

For example, process of diagnostic instrument diagnosis the vehicle fault as follows: 1, the diagnostic instrument send diagnostic service request message to car interior ECU (quill mainly includes the BCU and HCU and IPU)via the UDS diagnostic services ;2, car interior ECU response diagnosis request and send response message to diagnostic instrument when it received a request message;3,diagnostic instrument sends the response message to the cloud computing platform, then cloud computing platform uses the BP neural network to handle the data, and return the results to the diagnostic software to complete the fault diagnosis of vehicle ABS.

4.2 The corresponding relation between diagnosis function and diagnostic services

The current domestic and foreign vehicle fault diagnosis instrument is commonly used to read the fault code , clear fault codes, read the dynamic data flow and version information, write VIN code(Vehicle Identification Number), so in this paper is also developing the above five main functions for design of the automobile fault diagnosis system .This article is develop the function of each diagnostic function corresponds to a certain UDS diagnostic services based on the UDS diagnostic services, the corresponding relations as shown in table 1[6].

Table 1 The corresponding relation between diagnosis function and UDS diagnostic services

Diagnosis function	UDS diagnostic services
Read the fault codes	Read the fault information(SID=0x19)
Clear the fault codes	Clear the fault information(SID=0x14)
Read the version	Read data(SID=0x22)
Read the dynamic data flow	Read data(SID=0x22)
Write the VIN codes	Write data(SID=0x2E)

4.3 The CAN message transformations with Bluetooth message

Because of the difference format between Bluetooth message and CAN message, it need to design a rule to transfer the format between Bluetooth message and CAN message. Firstly, analysis the CAN message features, it mainly includes 8 bytes of data and 11 CAN ID identifier, it need to include these two information in the Bluetooth message, in order to determine a frame data where to begin, it need to define a data frame head to identify at the same time.in addition, to avoid error in the transmission process of the Bluetooth sending data, it need to increases 1 byte checksum at the end of each frame data , based on the above reasons, a rule to transfer the format between Bluetooth message and CAN message designed by this paper is: design of data frames that Bluetooth send to and received every time is: "1 byte frame head + 2 bytes CAN ID identifier + 8 bytes CAN message + 1 byte checksum", send to or receive a total of 12 bytes of data. When Bluetooth turn to CAN message instrument receives the message, it will extract CAN ID identifier, turn the CAN ID identifier of the CAN communication module in Bluetooth transfer to CAN message equipment into CAN ID identifier extracted from Bluetooth message, and the sent the 8 bytes CAN message of Bluetooth message to car interior ECU. When Bluetooth turn to CAN message instrument receives the response of the car ECU CAN message, it pack the CAN ID identifier and 8 bytes of data by sender into a Bluetooth data of "1 byte frame head + 2 bytes CAN ID identifier + 8 bytes CAN message + 1 byte checksum”, and sent to the mobile terminal via Bluetooth module, transformation rules as shown in figure 5.

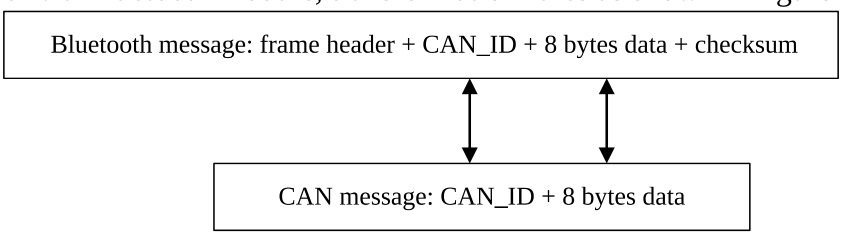

Fig. 5 The transformation rules between Bluetooth message and CAN message

5. The analysis of diagnosis result

Form a Hadoop cluster with 3 PC, a master node and two slave nodes. Install the vehicle fault diagnosis software on the Android mobile phone.

5.1 The testing of vehicle fault diagnosis software

The home screen of the vehicle fault diagnosis software is as shown in figure 6.

Fig. 6 The home screen of the software

As reading the data stream to example, the running effect as shown in figure 7, the left one is read the BCU data flow information, right quill is read HCU data flow information.

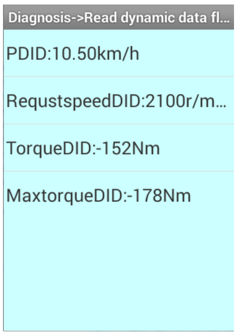

Fig. 7 The test of reading dynamic data flow

the test of Data flow information stored by platform BCU as shown in figure 5.11, data flow information storage of HCU as shown in figure 8.

```
char PDID[PDID_Num] = {0x00,0x65};
char requstspeedDID[requstspeedDID_Num] = {0x05,0x80};
char torqueDID[torqueDID_Num]  = {0x01,0x50};
char maxtorqueDID[maxtorqueDID_Num]  = {0x01,0x30};
```

Fig. 8 The data flow of information storage by HCU

By comparing the HCU actually flow of information data stored and data flow that from analysis of diagnosis system, with reference to the calculated actual physical values that to definition each of the data flow conversion formula by car manufacturer to verify the correctness of the results, function of reading dynamic data stream can be Judgment for running normally by comparison.

5.2 The test of cloud computing platform

This paper uses the three layers BP neural network to make vehicle ABS actuator fault generalization, to input data is extracted from corresponding ECU speed signal characteristic value, to output data is to coding of the corresponding cause of the problem, as the speed data eigenvalues of longitudinal velocity, lateral velocity and every round of the wheel to input values of networks, with the ideal output as the network output values. Taking the fault of ABS for example, the expression of regulator fault mode and fault type are shown in table 2.

Table 2 Expression of fault mode and fault type of ABS regulator

Input	Fault Mode	Output	Fault Type
x_1	Longitudinal speed	y_1	No fault
x_2	Lateral speed	y_2	The left front controller fault
x_3	The speed of left front wheel	y_3	The right front controller fault
x_4	The speed of right front wheel	y_4	The left rear controller fault
x_5	The speed of left rear wheel	y_5	The right reart controller fault
x_6	The speed of right rear wheel		

the fault mode $X=(x_1,x_2,x_3,x_4,x_5,x_6)$ as the input of BP neural network, the fault cause $Y=(y_1,y_2,y_3,\mathrm{y}_4,y_5)$ as the output of network in fault classification, the fault input element is 1 or 0 when the fault occurred by corresponding controller, output vector coding table of ABS regulator as shown in Table 3.

Table 3 Output vector coding table of ABS regulator

Code	Fault Type	The output of vector Y
A	No fault	(0 0 0 0 0 0)
B	The left front controller fault	(0 1 0 0 0 0)
C	The right front controller fault	(0 0 1 0 0 0)
D	The left rear controller fault	(0 0 0 1 0 0)
E	The right reart controller fault	(0 0 0 0 0 1)

The diagnosis result is shown figure 9.

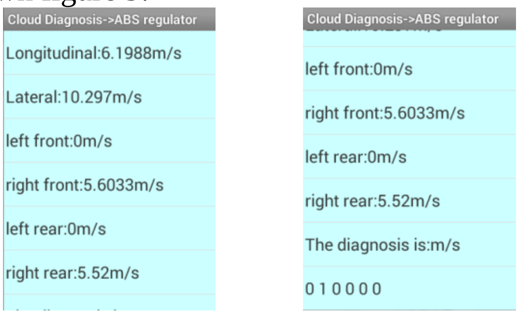

Fig. 9 The diagnosis result

It can be seen from the result, speed is (6.1988, 10.297, 0, 6.1988, 0, 5.52), the diagnosis result is (0 1 0 0 0 0), and the diagnosis is left front fault according to table 3, so design scheme of all the vehicle fault diagnosis system based on cloud computing is feasible.

6. Conclusion

The examples above have verified the vehicle fault diagnosis System based on cloud computing in this paper. The cost of fault diagnostic soft based on Android IOS is inexpensive, and it is also easy to be carried, reducing the hardware overhead. Storing all the data and algorithm in Cloud, user need not to know the meaning and purpose of the data and diagnose car fault easily using the diagnostic system. Because of analyzing data formidably, it can train Back Propagation neural network quickly and increase the accuracy of fault diagnosis.

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