A Modified Fuzzy Feedback Scheduling Strategy in CAN Network

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Abstract—In order to be able to comprehensively consider both network communication control performance and network communication in the network control system, and to balance the network resources, improve the network performance, this paper proposes a new information distribution of CAN data identifier , and adopts a improved fuzzy maximum priority scheduling strategy. This paper proposes a design of information distribution in the communication message identifier domain for CAN bus, and adopts a modified fuzzy maximum priority scheduling strategy based on feedback to calculate the message priority of communicating message. Identifier domain information is distributed into message ID and node number. Message ID is updated by scheduling calculation, and the node number is set initially remaining unchanged. This can ensure the CAN data identifier domains do not conflict. The fuzzy priority scheduling strategy takes loop control error, error change and network latency as the input of fuzzy control algorithm and it dynamically updates priority of each loop in the network control system.

Keywords-communicating message identifier; fuzzy priority scheduling; priority; delay; output error; error change

I. INTRODUCTION

In the Networked Control System (NCS), sensor, controller and actuator and other distributed object nodes interact with information through the network [1].The performance of control loop in NCS is not just depending on the design of control algorithm, and it also depends on the scheduling of network resources[2]. How to make full use of limited network resource or how to design scheduler in order to realize the optimization of control performance, has become one of hot topics in the research of current network control system.

Most real-time scheduling algorithms are open-loop scheduling algorithm, such as rate monotonic scheduling algorithm for CPU scheduling proposed by Liu[3], and dynamic scheduling algorithm based on task time limit proposed by Liu and Layland [4]. The Open-loop scheduling decision is based on the worst case of parameters estimation, and this scheduling decision makes large system redundancy and it cannot adjust dynamically with the changing of load. Feedback scheduling can adjust the parameters of the task or scheduling according to feedback information, and it has made large progress in recent years. Paper [5] designs a feedback scheduler based on the mathematical optimization method of dynamic bandwidth ; In this paper[6], a dynamic scheduler of the network control system is designed based on feedback mechanism; Paper [7] puts forward a scheduler combining dead zone and priority distribution of node; Paper [8] introduces the idea of integrated control and scheduling into the study of multi-loop NCS; Paper [9] designs a integrated fuzzy feedback scheduler; Paper [10] considers time-delay as the main factor which has greater influence on the performance of the network, and designs the network controller optimization based on QoS; Paper[11] take both system error and error change rate into consideration and designs fuzzy feedback scheduler which uses fuzzy maximum priority algorithm to adjust the priority of network control loops. Some of these studies only consider network communication, some only focus on the control performance of the network. They lack comprehensive consideration of both network communication and control performance.

This paper proposes a modified fuzzy feedback scheduling strategy which adjusts the priority dynamically based on CAN network, and it applies comprehensive consideration of time-delay, control error and error change rate of each control loop in the network. Based on this consideration, the strategy dynamically adjusts communication priority of each control loop, satisfies the real time request of NCS, and makes the network have a better quality of service. The simulation results proves that the proposed strategy can improve the robustness of network control system and control performance more effectively.

II. SYSTEM STRUCTURE SUPPORTING FUZZY PRIORITY SCHEDULING STRATEGY AND MESSAGE IDENTIFIER FIELD

A. System Structure Design

Network delay will make the system control performance degrade even become unstable[12],[13].

Therefore, it is necessary to be incorporated into overall consideration in the system resources integrated scheduling. Network delay includes sending delay, processing delay, waiting delay, transmission delay and accepting delay. Of these, waiting delay is taken as the main part. Considering that the time-delay from sensor to controller is measurable and the time-delay from controller to actuator happens after the control signal sends. For the controller, the time-delay is unknown, so in this paper, as shown in Fig .1, multi-loop NCS is analyzed.

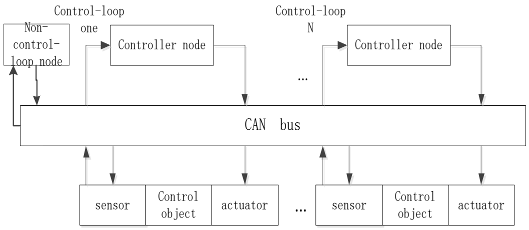

Figure 1. Networked control system

N control-loop nodes and some non-control-loop nodes share the same CAN bus. Each control loop consists of sensor, controller and actuator node, and the nodes transmit data through CAN network. The communication priority of control loop is implemented by fuzzy feedback scheduler. The fuzzy feedback scheduler is embedded in the controller of each loop, and it adopts the modified fuzzy maximum priority scheduling strategy based on feedback . The inputs of scheduler include network latency, control error and error change rate; The output of scheduler is the communication message ID of control-loop. If there are two or more same communication message ID of different control-loop, they use their own node number as their priority.

B. Design of Message Identifier field

CAN data frame structure is shown as Fig .2, and there are 11 or 29 bits for identifier in the arbitration filed. The identifier has two functions: the first is used for bus arbitration (priority) and The second is used for data routing (identify different nodes of different types of data). The priority of the CAN bus node is determined by the node identifier, and this requires data send by different nodes must have different identifier from each other.

Start of Frame	Arbitration Field	Control Field	Data Field (0~8bytes)	CRC Field	ACK Field	End of Frame

Figure 2. Structure of CAN data frame

In the CAN version adopted in this paper, the identifier has 11 bits. The paper divides 11 identifier filed of CAN data frame into scheduler message ID and the node number, as shown in Fig .3. Message ID represents the priority of a control loop, and updates dynamically with fuzzy scheduling computation; On behalf of the number of each node, the node number is set initially and remain the same. If we assume that the 11 identifier filed assigns m bit number to be the message number of node number , and assigns n bit number to be the message number of node number, then the sum of m and n is 11, and in the system there are at most 2^m nodes (each node has a different and unique node number). If there are 128 physical nodes in the system, we can take m as 7, then n is 4.

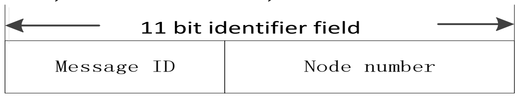

Figure 3. Information distribution of identifier field

The updating and calculating of message ID adopts scheduling strategy in controller node of each loop. All the communication message ID are set as 1111 at start (1 for stealth, 0 for dominant). then the message priority only relates to the node number. When the scheduler needs to improve the priority of loop according to the input , it will put loop communication message message ID forward bit by bit by updating 1 to 0, and got the needed message ID finally. When the controller send message to the network, the actuator and sensor will read the message and update their own message ID, and realize the update of loop message ID.

III. THE FUZZY PRIORITY SCHEDULING STRATEGY

A. Fuzzy Scheduling Algorithm

Based on the fusion of language experts and real-time data, the fuzzy scheduler based on feedback can get an effective dynamic management strategy of priority. It is mainly composed of fuzzy interface, rules library, fuzzy reasoning machine and interface four parts.

The inputs of the fuzzy scheduler are output error e, error change ec and network delay t. After fuzzification, they become E, EC 和 T, and their fuzzy sets are E={NB, NS, ZE, PS, PB}, EC={NB, NS, ZE, PS, PB}, T={L, M, H}; The output is the message priority of loop p, and becomes P after fuzzification. Its fuzzy set is P={PS, S, M, B, PB}. Network delay of loop is gained in the controller and it only concludes the delay from sensor to controller. According to the equal message ID of sensor, controller and actuator in the same loop, the delay calculated here is proportional to actual delay, so we can instead the calculated delay of actual delay.

Assume that the actual scopes of e, ec, t, p respectively are [-1,1], [-1,1], [0,2] and [1,5]; The membership functions of inputs and output are shown in Fig .4.

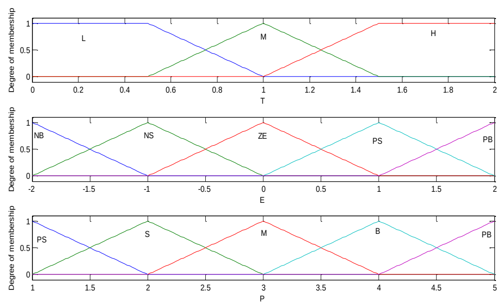

Figure 4. member function of fuzzy variable

The control rules of this article is based on the analysis of the relationship beteen the output error and error change and the loop network latency. If the loop has great network latency, the loop becomes a high priority whatever control error and error rate of change are; If the loop network latency is small, the loop becomes a low priority whatever control error and error rate of change are; If the loop has a center network latency, then it should continue to compare the control error and error change of each loop. Fuzzy control rules are shown in table 1 below.

TABLE 1. fuzzy control rules

Rules	T	E	EC	P
1	H	---	---	PS
2	L	---	---	PB
3	M	ZE	ZE	PB
4	M	ZE	Not ZE	B
5	M	PS	ZE	B
6	M	PS	NS	M
7	M	PS	PS	M
8	M	PS	NB	S
9	M	PS	PB	S
10	M	PB	ZE	S
11	M	PB	Not ZE	PS
12	M	NB	ZE	S
13	M	NB	Not ZE	PS
14	M	NS	ZE	B
15	M	NS	NS	M
16	M	NS	PS	M
17	M	NS	NB	S
18	M	NS	PB	S

In the table .1, -- means no matter what value the variable is.

Through the fuzzy reasoning, priority configuration of each loop reflects the correlation of system network delay, loop error and error change. What is more, it is a more appropriate performance of the system response. Using mamdani fuzzy inference machine and average center defuzzy-interface, then we take the fuzzy output down to the nearest whole unit, which is the final output as the updated message ID.

B. Scheduler Working Flow

Select a node for synchronous clock radio. After listening to the synchronous signal, each node will make local time be zero. This is to make each node in the loop be clock synchronization, and is to ensure accurate acquisition and calculation of loop network latency. Then, when the controller detects message, it will get and apply the message from corresponding sensor through identifying node number. When the controller starts controlling algorithm, the scheduler embedded in the controller will calculate loop network delay, output error and error change. With the input of the three factors , the scheduler calculate the message ID and then the controller will update its message ID. When the controller send message to the actuator, all the nodes in the network can listen, but the corresponding sensors and actuators can read update corresponding message ID by identifying node number. By this way, all the nodes in the control loop can update their massage ID. A work flow is shown in Fig .5.

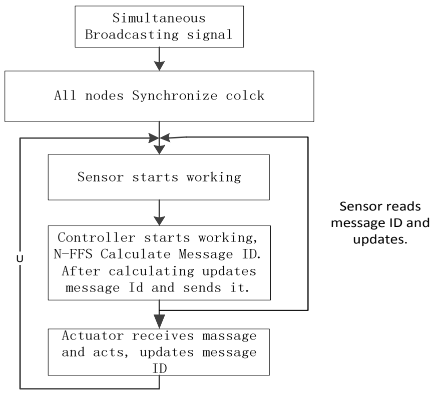

Figure 5. working flow of control loop

IV. RESULT AND ANALYSIS

The experiment adopts TrueTime1.5 simulation platform [14]. The simulation model contains four control loops, and each loop includes a sensor, a controller and a actuator node. Besides, the model also contains a interference node. All nodes Share one CAN network. The controlled object of every control loop is the dc motor model and its transfer function is $G(s)=\frac{1000}{s(s+1)}$; we set the sampling period as 9 ms; control algorithm adopts PID control algorithm. Network interference node randomly send packet to network, and interference node occupies 50% bandwidth.

First, analysis four loop data scheduling performance, compared with the situation without scheduling strategy: the situation without scheduling scheduling strategy the 4 loop has a big overshoot, but N - FFS is effective to reduce the system output overshoot, this is because that the scheduler can read the error information and delay information of loop 4 and then update the priority in real time scheduling cycle. This strategy improves the control performance of loop 4. The results are shown in Fig .6 and Fig .7.

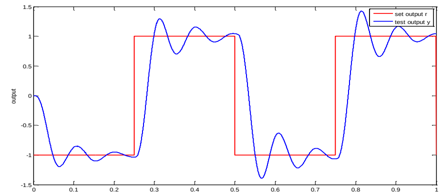

Figure 6. Output of 4 loop without scheduling

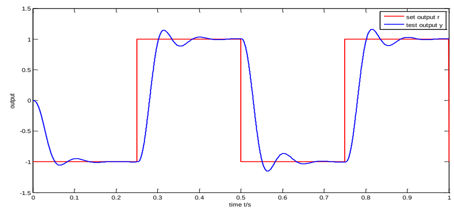

Figure 7. Output of 4 loop with fuzzy scheduling

Second, the results of each control loop can show the scheduling performance of the two situations, as shown in Table 2. Here, The rise time is when the actual output y reached 0.9 times of the reference output r for the first time the time; The overshoot δ refers to the maximum value of difference between transient response and steady-state value.

Result	situation	Loop	Loop2	Loop	Loop4
Overshoot σ	Without scheduling	1.051	1.148	1.240	1.370
	With scheduling	1.170	1.135	1.150	1.120
上升时间 t/s	Without scheduling	0.3006	0.3016	0.3526	0.3541
	With scheduling	0.3513	0.3026	0.3520	0.3516

In the constrained resource network system, the fuzzy priority scheduler can make low priority loop data perform better, and update priority more timely. Using proposed scheduling strategy, the network gets a good balance and improves the performance and the control performance of the whole network system.

V. CONCLUSION

Considering the output error and error change, the fuzzy priority scheduling proposed in this paper also takes the network delay which seriously influences network control performance into consideration at the same time. Through the calculation of three parameters, scheduler updates message priorities dynamically, and realizes the equilibrium of the control performance of each loop in network system which improves the control performance of NCS. Scheduler identifier information distribution has advantages. First, the setting of node number ensures that a message ID is each node can still identify and read the required information after updating message ID; Second, it ensures all the CAN data identifiers do not conflict. The disadvantage of identifier information distribution is that, with the increase of nodes number in the system, the sensitivity of scheduler adjusting message ID will degrades. This is caused by the definition of the parameter m, we can further discuss the definition of m to optimize the scheduler.

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