Model and Analysis of Multitasking Testing System Based on Network

Jin Guo, Qinkun Xiao and Zheng Qiu

Abstract—To improve the system performance of multitasking testing system based on network, builds the model of multitasking testing system based on network by using TrueTime toolbox and Simulink module of the Matlab, simulates the different network types, gets data transmission rate and packet loss rate by the TrueTime Network, analyzes the performance of multitasking testing system respectively based on CAN bus and Ethernet, discusses the performance of network control multitasking testing system with the different data transmission rate. The calculation result shows that the multitasking testing system output curve with CAN bus has the small overshoot, short adjustment time, and quickly reach stability; the data transmission rate is 800kbits/s, the multitasking testing system has better performance than the data transmission rate is 80kbits/s according to the multitasking testing system output curve, improves the data transmission rate can effectively reduce the time delay.

Keywords—multitasking testing system, data transmission rate, time delay, stability.

I. Introduction

The sensor collects information from the controlled object, sends the collected and processed information to the controller through the communication network, the controller sends the control signal according to the control algorithm to the actuator through the communication network, the actuator receives the control signal and acts on the controlled objects, constitute the closed-loop, distributed control system, it is known as the multitasking testing system[1]. In the study scheduling algorithms of networked control system, analyzes the networked control system model of three controlled objects in two data packet tasks and three data packet tasks, verifies the validity of EDF scheduling algorithm[2]. According to Truetime toolbox, establishes the simulation platform of multitasking multitasking testing system based on CAN bus, illustrates the improved IMTS scheduling algorithm have the better dispatching effect[3]. To test and verify the feasibility of the multitasking testing system scheduling algorithm, sets up multitasking testing system model of the five controlled objects, simulates and analyzes the advantages and disadvantages of different scheduling algorithms and applications[4]. Under the conditions of the network schedulability and system stability, calculates the sampling period optimization of three controlled objects based on RM scheduling, analyzes the optimized sampling period to get better control effect for system. This paper establishes the multitasking testing system model of the three controlled objects, analyzes interference, packet loss rate, time delay and data transmission rate of multitasking testing system, compiles the program of the sensor, the controller and the actuator, the simulation result shows the different control performance of the networked control system with different network data transmission rate, different network types and different time delays[5].

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II. True Time Toolbox

In order to analyze the multitasking testing system, the simulation toolbox must be able to reflect the control system and data transmission system, takes into account these two characteristics, develops the TrueTime toolbox by scholars such as Martin Ohlin, Dan Henriksson and Anton Cervin at Lund Institute of Technology in Sweden[6]. The TrueTime toolbox includes the TrueTime Kernel, the TrueTime Network, the TrueTime Wireless Nerwork, the TrueTime Send and the TrueTime Receive.

This paper uses the TrueTime Network to simulate the data transmission rate, packet size and packet loss rate and other network parameters, analyzes the various types parameters on the multitasking testing system performance[7]. The TrueTime Network module is used as communication nodes in the multitasking testing system, can transport data packets in system, among them, the network type is used to set the type of control network, the number of node is employed to set the module number, the data rate is made use of setting the data transmission rate, the minimum frame size is applied to set the shortest frame length, the loss probability is utilized to set the network data packet loss rate, the initial seed is exploited to set the starting value of the location[8]. The TrueTime Send and the TrueTime Receive use in single input interface and single output interface of multitasking testing system, builds stand-alone nodes by single input interface and single output interface, the TrueTime Send and the TrueTime Receive can mix with the kernel module to build the complete multitasking testing system model, needs to compile program by MATLAB or C++[9].

III. The Characteristics Of Different Network Types

In Ethernet, the communication nodes use the CSMA/CD protocol, the characteristic of this protocol that the system nodes must listen to the status of network before sending the message, if the status of network is busy, the system node waits until the status of network is idle before sending the message, otherwise, the message sends immediately[10]. If the status of network is unwanted, multiple nodes send messages at the same time, happens collision caused the interruption about sending messages. In this case, if the node intercepts that there is a lot of information in the network, the node waits a random length time and tries again before sending the message[11]. The disadvantages of Ethernet that random delay affects the transmission of data packets in the network, especially the status of network is heavy load and the collision of data packets is serious, the data throughput of the network declines at this moment, induces the network time delay, the time delay is random, no upper bound. If Ethernet employs the multitasking testing system, only applies to the situation that the status of network is light load. When the network load is too large, bring about the random and unbounded delay, this network type is not suitable for multitasking testing system.

The CAN bus protocol uses carrier-frame multi-access /message prioritized arbitration protocol[12]. The CAN bus protocol adopts the multi-master contention architecture, the each node of network can distinguish between master and slave send information to other nodes at any time, namely, each node has access to the network when the network is idle. If multiple nodes send messages to the network at the same time, produce conflict, makes use of the principle of bit-by-bit arbitration, draw support the identifier of the beginning part in the frame, continue to send messages with the higher priority nodes, take the initiative to stop sending data until the network is idle and then transmit with the lower priority nodes, therefore, there will be no node conflicts and will be avoided network congestion. The advantages of CAN bus that the transmission signal applies a short frame structure, has the ability of anti-interference, if the node generates serious error, possesses the function of automatic shutdown output , is provided with high reliability.

IV. Controller Regulation

Proportional-Integral-Differential controller is a common feedback loop component in industrial control applications. It consists of proportional unit, integral unit and differential unit. Proportional Integral Differential controller is called PID controller, proportional unit is P, integral unit is I and differential unit is D. PID control is based on proportional unit control, integral unit control eliminates steady-state errors but may increase overshoot, differential unit control accelerates the response of large inertial systems and reduces overshoot tendency[13]. Figure 1 shows the block diagram of the conventional PID control system, the control deviation is obtained according to the given value and the actual output value, the given value is r(t), the actual output value is c(t), the control deviation is shown by (1).

$$e(t) = r(t) - c(t) \quad (1)$$

Control law is expressed by (2).

$$u(t) = K_P \left[e(t) + \frac{1}{T_I} \int_0^t e(t)dt + T_D \frac{de(t)}{dt} \right] \quad (2)$$

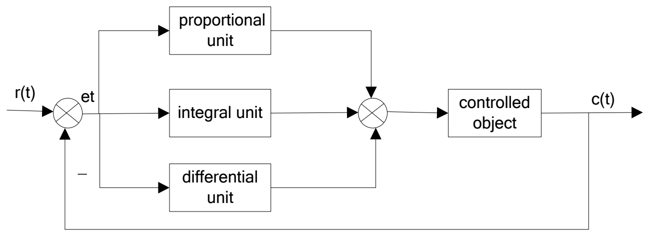

Figure 1. The block diagram of the conventional PID control system

In (2), proportional coefficient is K_P , integral time constant is T_I , differential time constant is T_D .

Proportional link that the system deviation signal can be quickly responded to the proportional control, when there is deviation occurs the control system, the control will soon be issued by the controller, the deviation will be greatly weakened. However, proportional control also has its shortcomings, the steady state error is proportional control can not eliminates, the increase of K_P makes the control system instability phenomenon[14].

The main role of integral part is to be able to eliminate the static error, if the deviation appears in the system, the integral control of the deviation continues to accumulate, the deviation is the output of this integral control eliminating the amount of control, system eliminates the error completely, which is only a matter of time for integral control.

The integral time constant determines the intensity of the integral control action, the strength of the integral action is inversely proportional to the integral constant, the smaller the integral constant is, the stronger the integral function is, if we want to weaken the integral function, should adjust the integral constant smaller. Integral control in the integral role is not the stronger the better, if the integral effect is too strong, then the overshoot becomes larger and the phenomenon of shock appears in the control system. In the differential part, the future trend of the deviation signal can be monitored by differential control, differential control can overcome the occurrence of system turbulence and suppress the overshoot of the system, the performance of the differential control system optimized to make the system more stable, the system’s dynamic response speed will be improved so that the adjustment time is also reduced.

PID controller parameter tuning designs the core of control system, it is based on the characteristics of the controlled process to determine the PID controller proportional coefficient, integral time and differential time.

PID controller parameter tuning have many methods, sums up two categories. One category is the theoretical calculation of tuning, it is mainly based on the mathematical model of the system through theoretical calculations to determine the controller parameters, obtains calculated data by this method may not be directly used, must be adjusted and modified by practical engineering. Another category is the engineering tuning method, which relies mainly on engineering experience, is directly carried out in the control system test, and the method is simple, easy to grasp, is widely used in engineering practice.

PID controller parameters of the engineering tuning methods, there are critical ratio method, the reaction curve method and attenuation method. The three methods have their own characteristics, the common ground is through the test, and then adjust the controller parameters in accordance with engineering experience formula. However, no matter which method is adopted, the controller parameters need to be adjusted and perfected in the actual operation. Now generally used is the critical ratio method.

Use this method to set PID controller parameters as follows:

1) Select a sampling period short enough for the system to work.

2) Only add the proportion control until the system has a critical oscillation to the input step response, note the proportional amplification coefficient and the critical oscillation period at this moment.

3) Calculate the parameters of PID controller through the formula under a certain degree of control.

PID controller uses wide range, flexible use, and already a series of products, the use of only three parameters can be set, these parameters are K_P, T_I, T_D, in many cases, not all three parameters are required, one or two of which may be taken, but a proportional control unit is essential.

PID controller has a wide range of applications, while many industrial processes are non-linear or time-varying, they can be transformed into systems that do not vary substantially in time with linear and dynamic characteristics by simplifying them, so that the PID can be controlled.

PID parameters set simple, namely, the PID parameters can be set in time according to the dynamic characteristics of the process. If the dynamic characteristics of the process change, for example, the dynamic characteristics of the system may change due to changes in the load, the PID parameters can be readjusted.

PID controller is constantly being improved in practice. PID controller does not work well when it comes to controlling complex processes that are non-linear, time-varying, coupled, and uncertain parameters and structures, most importantly, if the PID controller can not control the complex process, no matter how the parameters are used. Despite these shortcomings, PID controller is the best controller.

V. Calculation Analysis

The model of multitasking testing system builds by the TrueTime toolbox, the system have three controlled objects, the controlled object is DC motors, and the transfer function is $G(s)$, $G(s)=1000/(s^2+s)$, the controller algorithm uses proportional and derivative. The controlled objects connect separately with the sensor, the sensor sends the sampling instruction through the network, and transmits the sampled value to the controller, the controller calculates the control algorithm and sends along the control signal to the actuator through the network, realizes real-time control of the controlled object.

A. Data Transmission Rate and Time Delay Analysis

The controller of the three controlled objects adopts the PID algorithm, the DC Servo 1: the proportion coefficient is K_P, $K_P=0.5$, the differential coefficient is T_d, $T_d=0.7$, the differential gain is N, $N=20$,the sampling period is h, $h=0.1$; the DC Servo 2: $K_P=0.8$, $T_d=0.7$, $N=20$, $h=0.1$; the DC Servo 3: $K_P=0.9$, $T_d=0.5$, $N=20$, $h=0.1$.

Assuming that the network type is CAN bus, the input signal is square wave signal, the interference is 0.1, the packet loss rate is 0.1, the delay is 0.1s, and the data transmission rate is 80kbits/s. The output curves of the three controlled objects are shown in Figure 2, When the transmission rate increases to 800kbits/s, the output curves of the three controlled objects are shown in Figure 3.

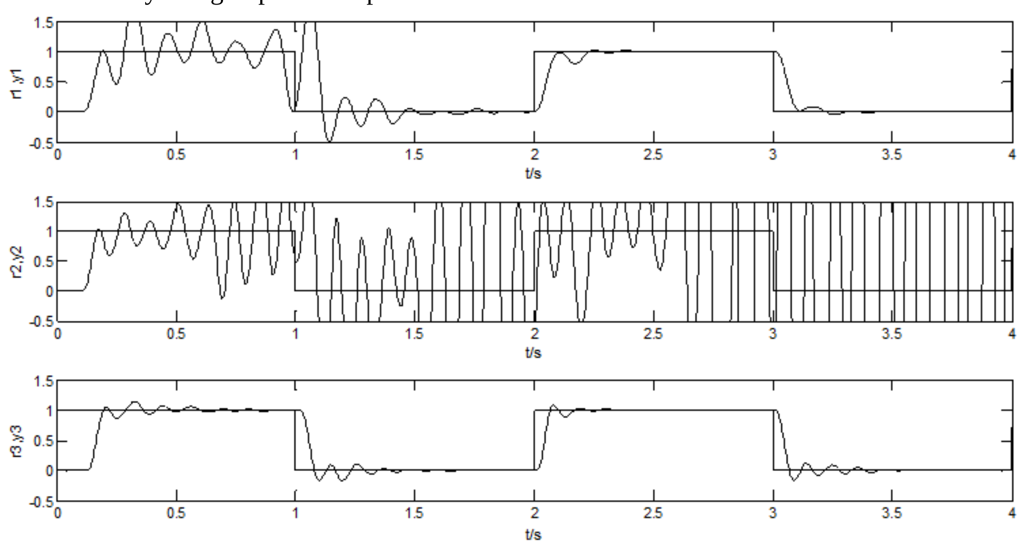

Figure 2. The system output curve when transmission rate is 80kbits/s and time delay is 0.1s

It can be seen from Figure 2 and Figure3 that the output curve of a controlled object is violently oscillated and the curve is divergent when data transmission rate is 80kbits/s, the output of the controlled object can not follow the input and the system control performance is poor. When data transmission rate increases to 800kbits/s, the three controlled objects can quickly follow the system input, the control effect of multitasking testing system is better, because the data transmission rate increases, which can reduce the time delay, improve the stability of multitasking testing system.

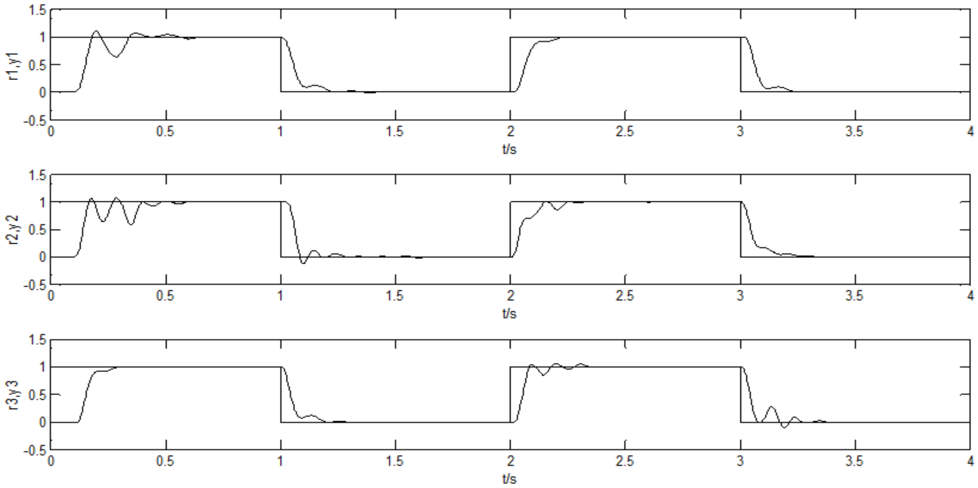

Figure 3. The system output curve when transmission rate is 800kbits/s and time delay is 0.1s

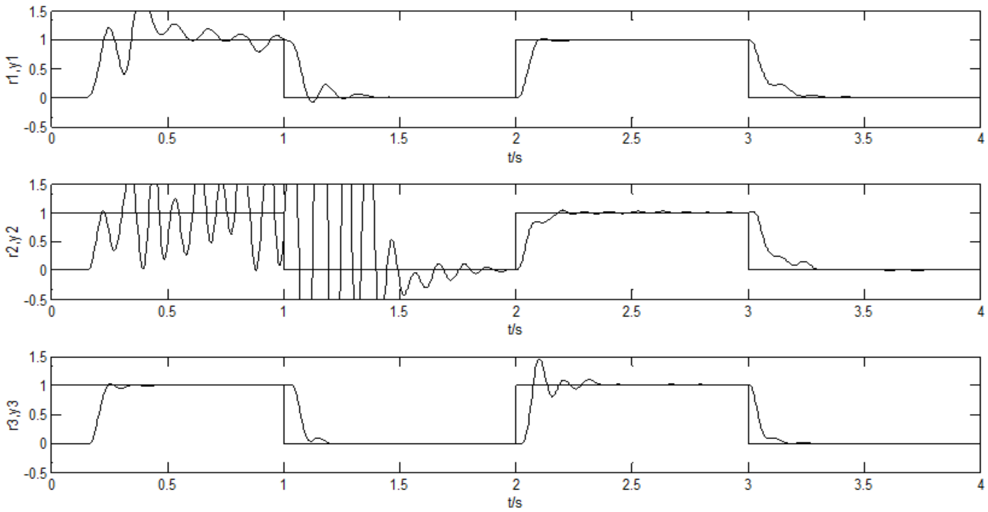

Figure 4. The system output curve when data transmission rate is 800kbits/s and time delay is 0.15s

Supposing that the network type is CAN bus, the input signal is square wave signal, the data transmission rate is 800kbits/s, the interference is 0.1, the packet loss rate is 0.1 and the time delay is increased to 0.15s, Figure 4 is the output curves of the three controlled objects.

Figure 3 and Figure 4 show that the time delay increases from the system itself, the data transmission rate raises 800kbits/s, the time delay increases to 0.15s, the control quality of the system has greatly reduced, caused the system stability being reduced, the result that only improve the data transmission rate, can not make better the control effect of multitasking testing system.

B. *Interference Analysis*

Assuming that the network type is Ethernet, the input signal is square wave signal, the data transmission rate is 800kbits/s, the interference is 0.35, the packet loss rate is 0.1 and the time delay is 0.1s. Figure 5 is the output curves of the three controlled objects; Figure 6 is the output curves of the three controlled objects when the network type is CAN bus.

It can be seen from Figure 5 and Figure 6 that the system control effect based on Ethernet is poor under the same network transmission rate, the same data packet loss rate, the same time delay and the same interference, among them, the two controlled objects have the maximum adjustment time and bigger the dynamic deviation, shows distorted state; The network type is CAN bus, the control effect of system is relatively better, the output curve of the three controlled objects can follow the input signal, the multitasking testing system has better stability.

C. Networks Type Analysis

Supposing that the controller of the three controlled objects adopts the PID algorithm, the DC Servo 1: $K_P = 0.4$, $N = 25$, $h = 0.1$; the DC Servo 2: $K_P = 0.45$, $T_d = 0.6$, $N = 30$, $h = 0.1$; the DC Servo 3: $K_P = 0.4$, $T_d = 0.7$, $N = 10$, $h = 0.05$; the input signal is square wave signal, the interference is 0.15, the packet loss rate is 0.1, when the data transmission rate is 80kbits/s and the network type is Ethernet,

Figure 7 is the system output curves of the three controlled objects; changes the network type to CAN bus, the system output curves of three accused objects are shown in Figure 8.

The result of Figure 7 and Figure 8 that the system output curves based on Ethernet can not follow the input of the system, the system output curves based on CAN bus can quickly and better to follow the input signal when the data transmission rate is 80kbits/s, considers the packet loss rate and interference, verifies the CAN bus can adapt to the higher load environment, and has good stability and control effect.

When the data transmission rate increases to 800kbits/s, other parameters remain unchanged, the network type is Ethernet, Figure 9 is the output curve of the three controlled objects; change network type to CAN bus, the output curve of three controlled objects are expressed as Figure 10.

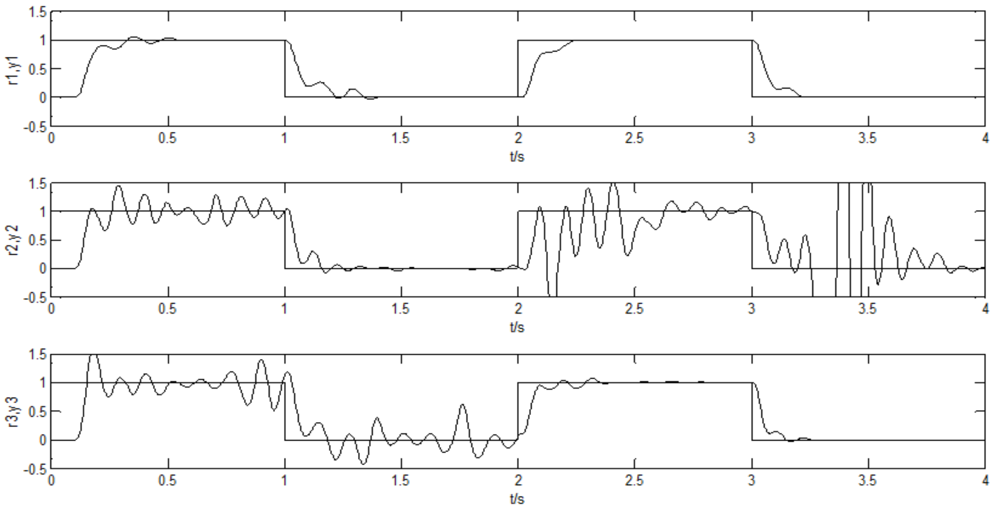

Figure 5. The system output curve when the network type is Ethernet

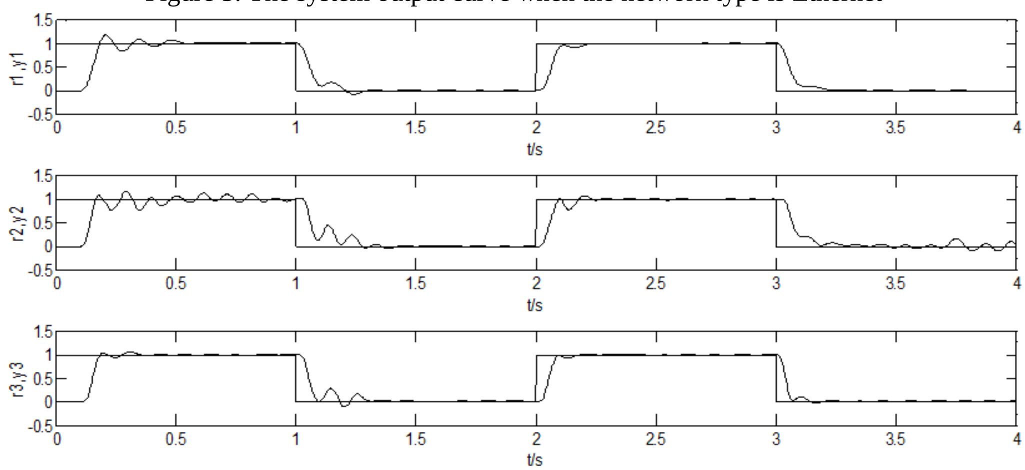

Figure 6. The system output curve when the network type is CAN bus

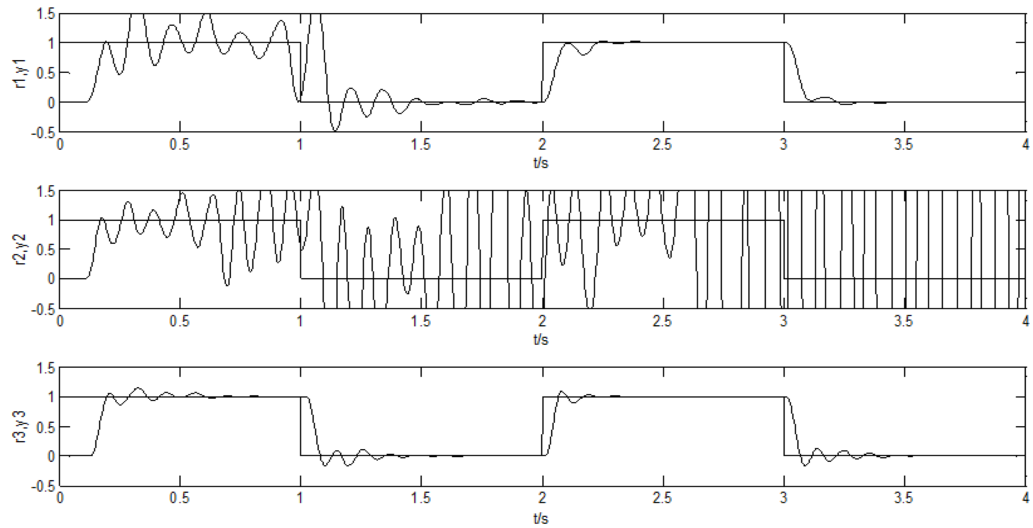

Figure 7. The system output curve when transmission rate is 80kbits/s and network type is Ethernet

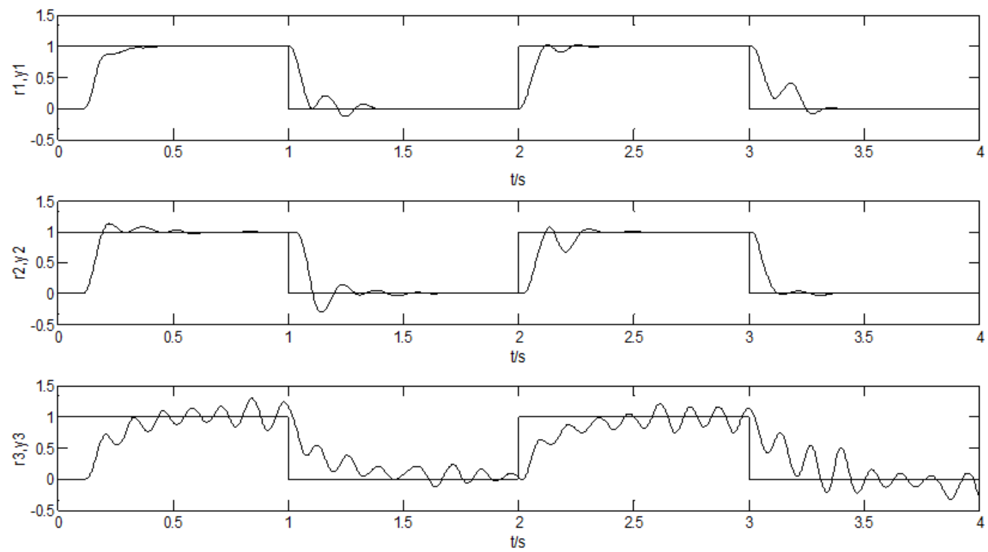

Figure 8. The system output curve when transmission rate is 80kbits / s and network type is CAN bus

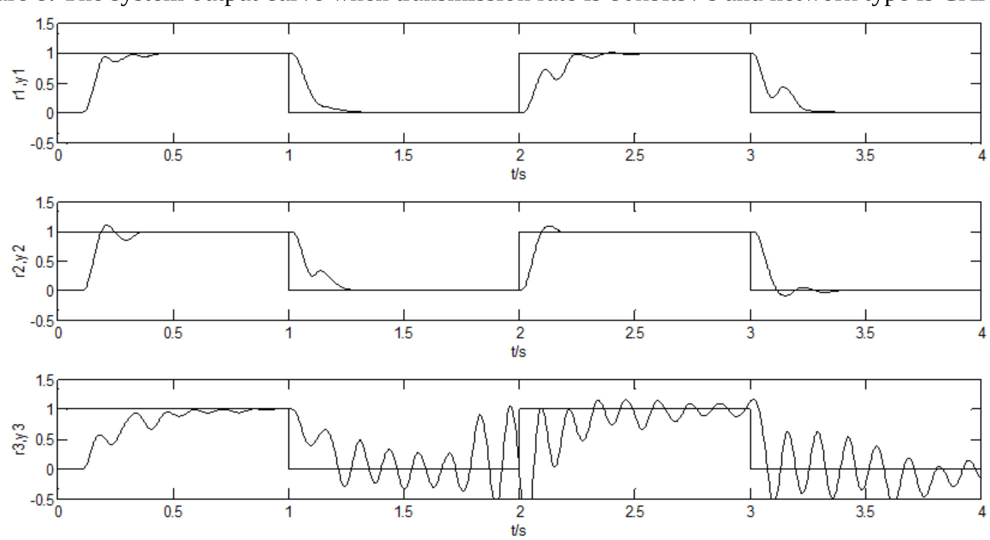

Figure 9. The system output curve when transmission rate is 800kbits/s and network type is Ethernet

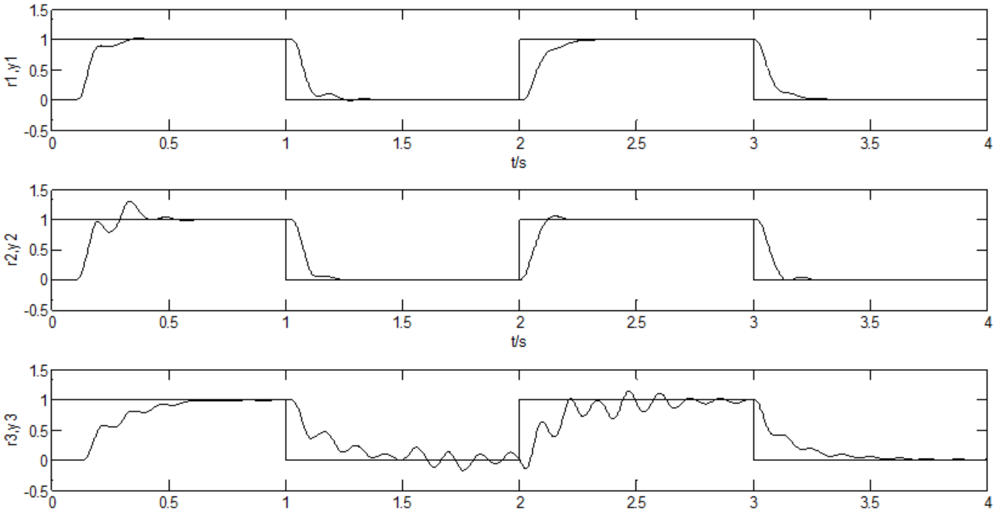

Figure 10. The system output curve when transmission rate is 800kbits/s and network type is CAN bus

It can be seen from Figure 9 and Figure 10 that based on Ethernet or CAN can improve the system control effect when the data transmission rate adds to 800kbits/s, when network type is CAN bus, the three controlled objects can follow the input signal, has the best stability and the strongest control effect.

VI. Conclusion

This paper establishes the multitasking testing system model of three controlled objects according to the different data transmission rates, network type and time delay, when the data transmission rate is increased from 80kbits/s to 800kbits/s, the time delay is 0.1s, the output of the three controlled object become stable, get shorter adjustment time, have smaller maximum dynamic deviation, whether the network is Ethernet or CAN bus; The data transmission rate increases from 80kbits/s to 800kbits/s, the multitasking testing system has better control performance based on the CAN bus. In order to improve the multitasking testing system's control performance and stability, needs comprehensive analysis from interference, data transmission rate, packet loss rate and time delay, provides the method and basis for remote data transmission by network.

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