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# The Remote Control System Based on the Virtual Reality

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*Abstract*—**Aiming at the issues of random delay and delay uncertainty of the control information network, a kind of network remote closed-loop control structure based on virtual reality simulation is proposed. The method in accordance with the idea of open-loop system to achieve closed-loop control make the influence of network latency excluded real-time little closed-loop control system of controlled object value and no effect on the characteristics of the controlled object. Simulation results show that the structure of the remote control system has good dynamic quality and reduce the impact of network delay aspects to the system dynamics characteristics. It is a reference idea to the remote real-time closed-loop control.**

*Keywords-Virtual Reality; Network Time-delay; Remote Control*

## I. INTRODUCTION

The network control system is the extension of the control distance, the long-distance transmission of control signals will inevitably bring about the delay of the signal [1-2]. Remote control system with Internet based on TCP/IP protocol as a means of information transfer can be achieved the purpose for control equipment connected to any node within the Internet at any time, any place [3-5].Remote control system based on control information network actually is pulled away the both ends of control system,

between the controller and the controlled object across a computer network to do the information transmission, but in such a system, the basic requirements of the control system has not changed, only increased the difficulty of control [6]. The experiments show that the larger delay produced a certain time delay and uncertainty during transfer in the Internet information, which will allow the entire system to control quality seriously deteriorated, and it's a bottleneck problem of impact the development of remote control technology based on Internet [7]. In order to relief the impact of network latency on system performance, we must seek new control concepts from the basic principles of the control system.

An open, interactive and realistic virtual environment created by virtual reality technology make people immersed in virtual reality to make decisions on changes in the environment based on virtual environments provided by virtual reality and to impact the virtual environment [8]. In the "real" virtual environment, the input is a set of virtual parameters, the output is another set of virtual parameters, the two parameters linked accordance with a set relationship, the operator can respond to the input parameters timely. Because the technology has a good "reality" and "forward-looking", this paper used the virtual reality simulation applied to network remote control structures and

accordance with the idea of open-loop system to achieve closed-loop control make the impact of network latency out of real-time closed-loop control system of the controlled object value. It's weak effectively the impact of network latency on the performance of the entire control system.

## II.    THE THREE CLOSED-LOOP REMOTE CONTROL STRUCTURES BASED ON VIRTUAL REALITY TECHNOLOGY

### A.    System Architecture

Transmission delay link of the network makes the time lag existed between remote operations and controlled object, there are difference between the operations can be based on parameters and needs based on the parameters resulting in the decision-making accuracy and the effectiveness of instruction. Shown in Figure 1, you can build a virtual operating environment for the remote operator by means of the actual controlled object and its control parameters of simulation model. In this environment, the simulation charged object is located in a remote client and no network transmission delay between the remote operators, the operator can real-time operation to the simulation charged objects. And at the same time the control signals $\gamma(k-1)$, $\gamma(k)$, $\gamma(k+1)$ imposed in the simulation charged objects delivery to the actual controlled object over the Internet and taken back continually the actual status information $y(k-1)$, $y(k)$, $y(k+1)$ of the controlled object, and real-time compare the state of its simulation controlled object to monitor the running state of the actual controlled object. The network delay will produce a similar delay influence for every transfer data, match the appropriate buffer technology can make to maintain continuous for data flow and make the control signal worked on the actual controlled object and taken back to the status signal to maintain a continuous to achieve real-time closed-loop control for the actual controlled object.
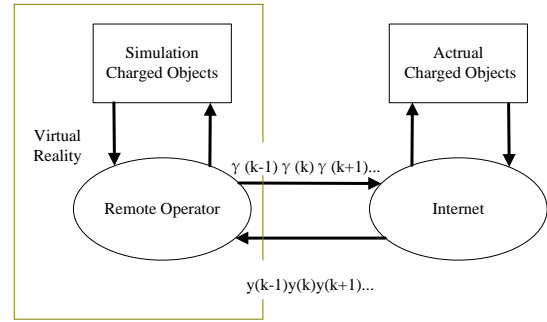


Figure 1.    Virtual Reality Environments Structural Diagram

Network latency makes remote real-time control has been limited, how to "real" reflect the actual system running status by means of the system model and operators develop and implement a control command according to the "real" virtual environment is the applications target of virtual reality technology in the remote control.

### B.    Application examples of Virtual Simulation Environment

In order to describe clearly the application background of virtual reality simulation, we made the application example shown in Figure 2 based on the virtual simulation environment. The left half of the figure is the remote operator to create a virtual simulation environment based on virtual reality ideas, including the display part and the control panel part, of course, this is a simple virtual reality environment, obviously, all the advantage of technology allowing operators into the reality and the technology and equipment facilitate operator to make a judgment and final operation can be used to create more complex and better functions virtual reality. The operating handle in the control panel in the figure is only a schematic which mainly used to describe a method based on virtual reality simulation environment remote control.

As shown in Figure 2, the schematic is a system for target tracking and the implementation of the fight against by a game controller in the control panel (one can shake the handle on the right control panel), the launch button (two buttons on the left control panel) and control objects in the operation display interface. First of all, the system   achieve the control objects and target of virtual reality association to

the actual control objects and target, that is virtual reality can be more true response to the physical environment, followed instructions in the control panel to be able to timely apply to the control object of actual environment. In the virtual simulation environment, operator consider only the running state of virtual reality, that is thought the display of the virtual simulation environment such as playing video games operation control object to track the target by game controller, then within the effective range launched the missile pursuit or shooting by launch button. When the target shoot down by players means the actual target has been shot down and task completed.
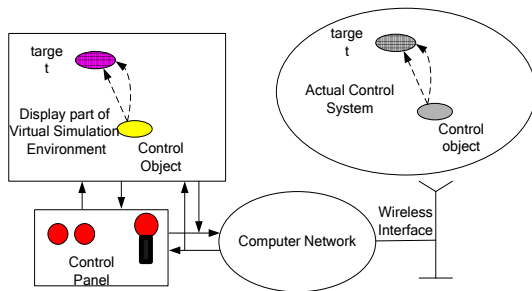


Figure 2.    An Application Example Based on Virtual Simulation Environment

## III.    THE THREE LOOP-CONTROL STRUCTURE OF VIRTUAL SIMULATION ENVIRONMENT

Due to the presence of network delay on the remote control made operator dialogue to the controlled object has time delay, to meet the good characteristics of the controlled object response and real-time closed-loop control of the remote control operator ,a three closed-loop remote control system based virtual reality simulation was proposed on concept of virtual reality which control the both ends namely the operating side and charged object side to create the independent control value closed-loop structure, the dashed box shown in Figure 3 as both ends of the dumbbell structure to meet real-time closed-loop control of the actual controlled object and the virtual simulation charged object to control value, connect both ends of located at operating side and dumbbell structure of charged object as a dumbbell handle through the Internet, big closed-loop with network delay thereby to build a dumbbell-shaped three closed-loop

structure. Small closed-loop at dumbbell both ends can be run independently by operators' instructions and the run command and result can be communicate with each other by middle big closed-loop-dumbbell handle to carry out a comparison of the information, interaction and updates of two little closed-loop system at dumbbells both ends. Visibility, in this structure, little closed-loop at dumbbells both ends can be run independently without network delay links, so there is a fast response speed to charged value. The dumbbell handle big closed loop with time delay links can use the actual charged object parameters at one end of the dumbbell structure according to the parameter variations of the both ends at dumbbell to modify continuously running parameters and status of virtual simulation system at the other end of dumbbell structure which make the running state of simulation system and actual system similar or even identical, while operator to virtual simulation running state of one end of system based on dumbbell structure to decide the next control instruction and judge the running state of the charged object and actual object whether identified according by running result of both ends of dumbbell structure, and judge actual system whether running normal in accordance with operating desired way. Therefore, in the three closed-loop remote control system, the operator can be give the required control instructions based on virtual simulation system and ultimately achieve the purpose of remote real-time control. See, the key to the system is how to create a virtual closed-loop architecture and network delay model, that is to establish a closed-loop control system of practical charged objects and their parameters, at the same time, to establish another set of the controlled object model as virtual real controlled object, then make the remote control "immersed" in the virtual reality of the controlled object model operate the controlled object model in virtual reality, while sent the operating instructions to the actual controlled object to achieve the purpose of real-time remote control the controlled object. In order to achieve the purpose of real-time control must be sent the state of the actual system into a virtual reality, so that controller can not only be implement real-time operating based on the object model in virtual reality, but also can monitor and compare the

actual running state of the actual controlled object constantly to understand three closed-loop remote control system of this dumbbell-shaped whether normal running and the pace of the small closed loop at both ends of dumbbell head whether functioning properly and take the necessary measures in accordance with this result. Therefore, the key of the structure is to accurately predict network delay and accurate establish the controlled object model.
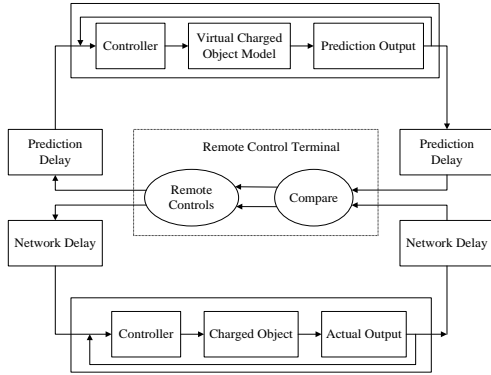


Figure 3.    Dumbbell-shapes' Three Loop-closed Structure Diagram of Remote Control

## IV.    VIRTUAL CHARGED OBJECT MODELING AND SIMULATION

Build a brushless DC motor remote control virtual simulation environment as shown in Figure 4 in accordance m function and simulink simulation module provided with the Matlab. The brushless DC motor model used the model provided in the Matlab standard library, one of the brushless DC motor due to large air gap ignored the rotor and the stator flux saturation, the magnetic flux as a linear function, and set the brushless DC motor worked in the way of two-phase conduction star-shaped three-phase six-state power supply, its mathematical model in abc phase plane establish a brushless DC the motor mathematical model [9-10]:

$$\frac{d}{dt}i_a = \frac{1}{3L_s}[2V_{ab} + V_{bc} - 3R_s i_a + \lambda p \omega_\gamma(-2\phi_b^{'} + \phi_c^{'} + \phi_c^{'})] \quad (1)$$

$$\frac{d}{dt}i_b = \frac{1}{3L_s}[-V_{ab} + V_{bc} - 3R_s i_b + \lambda p \omega_\gamma(\phi_a^{'} - 2\phi_b^{'} + \phi_c^{'})] \quad (2)$$

$$\frac{d}{dt}i_c = -(\frac{d}{dt}i_a + \frac{d}{dt}i_b) \quad (3)$$

$$T_e = p\lambda(\phi_a^{'} \cdot i_a + \phi_b^{'} \cdot i_b + \phi_c^{'} \cdot i_c) \quad (4)$$

where,

Ls-stator coil inductance

Rs-stator coil resistance

ia, ib, ic-a,b,c phase current

$\phi_a^{'}$, $\phi_b^{'}$, $\phi_c^{'}$ -a, b ,c opposite electromotive force

$V_{ab}$, $V_{bc}$ -line voltage between ab and bc

$\omega_\gamma$ - Rotor angular velocity

$\lambda$ - Rotor permanent magnet generated flux amplitude at the stator

$P$ -pole pair number

Te-electromagnetic torques

mechanical equations:

$$\frac{d}{dt}\omega_\gamma = \frac{1}{J}(T_e - F\omega_\gamma - T_m)$$

$$\frac{d\theta}{dt} = \omega_\gamma$$

where,

$J$ - sum of inertia of rotor and load

$F$ - sum of viscous friction coefficient of rotor and load
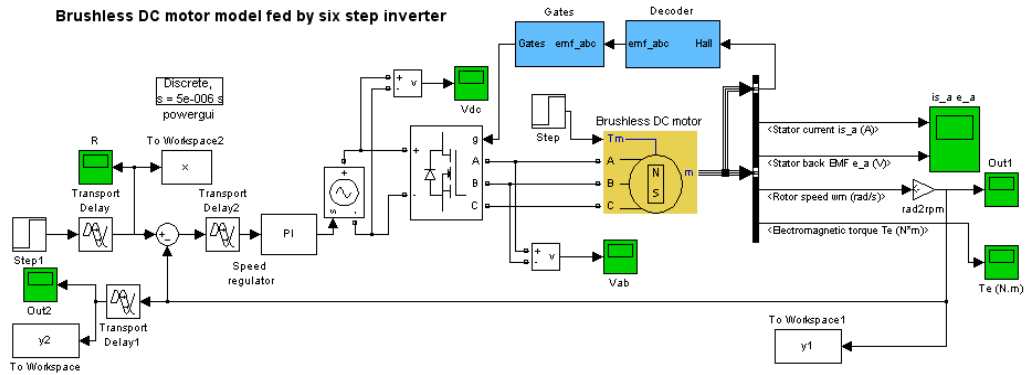
$T_m$ - mechanical torque of shaft

Figure 4.    Schematic Diagram of Brushless DC Motor Virtual Simulation System

Random set network delay is 0.1 seconds and set the parameters of the motor: $R_s$ (2.8750ohm), Ls (8.5e-3H), flux (0.175Wb), the top width of trapezoidal wave back-EMF (120o), moment of inertia (0.8e-3J), friction coefficient (1e-3F), and pole number (4P). Set the network delay is 0.1 seconds, a small closed-loop delay 0.0001 seconds, at t = 0.01 seconds add a step input ,and add 3N.m load torque Tm when t = 0.1 seconds then simulation, the result shown in Figure 5.

To learn more about the transmission delay of network, analyze the impact of transmission delay on both ends of the dumbbell-shaped virtual simulation environment as shown in figure 3. Assume that the simulation of the controlled object and the actual controlled object is exactly the same, the same model shown in Figure 8 also on behalf of simulation controlled object and actual controlled object. And step function as input, set to a value of 0 and 0.1 seconds of delay link "Delay" and "Delay1 respectively, which Delay2 is the

delay within the small closed-loop system, where is set to 0.001 seconds, you can get the results shown in Figure 5 after simulation run.

Which a diagram shows the control commands R issued from the operator (fine straight line as shown in figure) a direct work on the controlled object without delay, while the output out1 of controlled object (dotted line) is not extended and out2 (thick solid line) the delayed output. Figure b shows a control command $R_n$ issued from the operator after delay work on the controlled object, and the output out1n of the controlled object (dotted line) is not delay and out2n (thick solid line) was delay again output. Which R, out1, represent respectively the input and output of the simulation actual controlled object; $R_n$, out2n represents input and output of the actual controlled object; out1 and out1n represents the artificial delay output in order to compare the simulation objects and the actual object output in Figure 5.
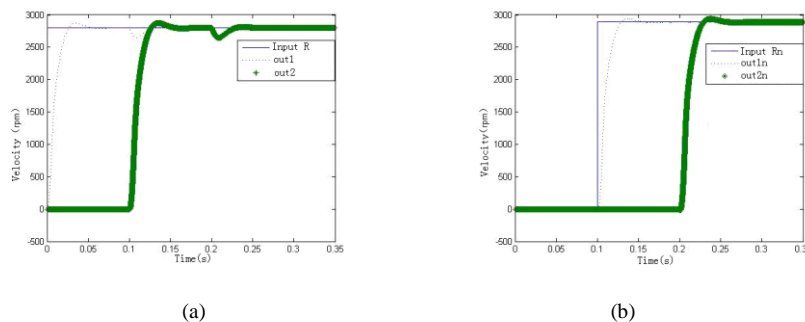


(a)                                        (b)

Figure 5.    Impact of Delay Links on the System Input and Output（a）Response Curve Without Delay (b) Response Curve Of The Input Delay

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A diagram in Figure 5 shows speed input R of speed small closed-loop of one end of the dumbbell structure does not contain the of the network delay (thin straight line as shown in the figure), the response values out1 (dotted line) and out2 value of the response after the network delay on closed-loop transmission (thick solid line); Figure b shows the input R of speed set in the other side of the dumbbell structure after through a large closed-loop network delay (a thin straight line), and response values out1 of system work on the input (dotted line), and the out2 of the response through the network closed-loop transmission delay (thick solid line). Which the one-way network delay time is 0.1 seconds, the delay value can be set by hand in the simulation, of course, can be projection product by the radial basis function network delay model.

## V. CONCLUSION

For the network closed-loop system of human controller as the study object combined with human characteristics as well as the requirements of network closed-loop control system, A method based on virtual reality simulation network remote closed-loop control was proposed. In this control structure, the idea of achieve closed-loop control in accordance with the open-loop system to exclude the impact of network delay on real-time closed-loop control system of the controlled object control value and no effect on the characteristics of controlled object; the charged object remote simulation system based on virtual reality simulation makes the object of fast, real-time remote control has been based; virtual reality simulation system itself constantly updated according with the actual environment changes to ensure that based on the virtual reality remote control has a certain authenticity. Simulation results show that the remote control system with this structure has good dynamic quality and reduced the impact of network delay links on the system dynamics characteristics which a reference ideas to the remote real-time closed-loop control.

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