System of Hardware-in-the-Loop Simulation (HILS) Applied to Yaw Velocity Based on ADSL Driving Simulator

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Abstract – This paper designs a preliminary architecture of hardware-in-the-loop simulation (HILS) applied to yaw velocity based on ADSL driving simulator. In this system, automotive dynamics and simulator interface module is based on driving simulator, taking AT89C52 micro-controller unit (MCU) as the center of control and actuator module, PC serves as operating console for monitor and communication module. At last, steady and dynamic analyze are proceeded.

Key words：Hardware-in-the-loop simulation, Yaw velocity, Driving simulator

1 Introduction

Hardware-in-the-loop Simulation (HILS) comes forth with the certain extent development of computer software and hardware. It has many advantages [1]. Yaw velocity is the significant criterion and controlled object of ECU of vehicle road-holding property. This paper designs a preliminary architecture of hardware-in-the-loop simulation system applied to yaw velocity based on ADSL driving simulator. In this system, yaw velocity computed by automotive dynamics of ADSL is simulated by actuator, and then is measured by sensor. Then we can transfer the signal to the control system which needs it. What's more important is that this system can use as the test bench of the ECU of controlling yaw velocity. This paper discusses the design of the system, including its function, hardware and software and so forth. The test for the system indicates that it is linear and responds fast.

2 Function

The function of the system is that simulating the yaw velocity by actuator, measuring and monitoring. The system consists of the three modules: automotive dynamics and simulator interface module, control and actuator module, monitor and communication module. The relationship of the three modules is shown in FIGURE 1.

Automotive dynamics of the ADSL driving simulator is the basis of the system. The data of yaw velocity computed and exported by automotive dynamics of ADSL is converted to electrical signal by simulator interface module, which then is transferred to the control and actuator module. The core of the system is control and actuator module which regulates the electrical signal and then transfers it to the MCU (AT89C52).The MCU controls the motion of the stepper motor. Then the rotate speed of the stepper motor is measured by gyroscope. The monitor and communication gets the rotate speed of the stepper motor, and then transfers it to PC which does other processing.

3 Hardware

3.1 ADSL driving simulator

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ADSL driving simulator which was designed by JiLin University State Key Laboratory of Automobile Dynamic Simulation, is a real-time dynamic simulation device integrated with automotive dynamics, input/output interface, operating platform and so on. We can get accurate real-time yaw velocity signal from the automotive dynamics. Then a little configuration of output interface is needed to obtain the electrical signal which is required by the system.

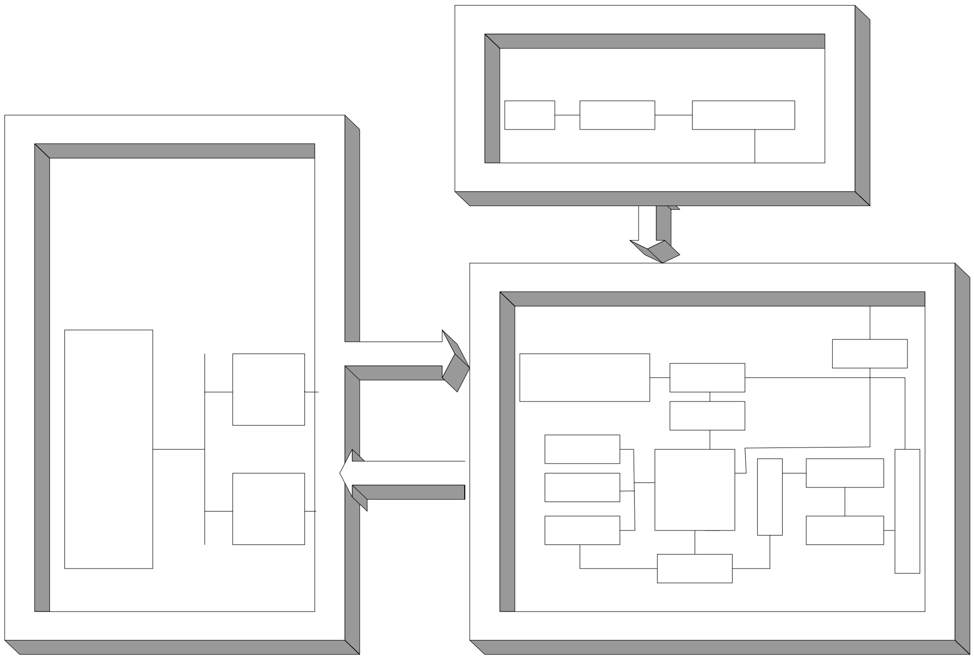

Fig. 1 System Framework

3.2 Design of control and actuator module

3.2.1 Sub-module of regulating analog signals

The electrical voltage signal of yaw velocity is transferred to control and actuator module drilling a distance. In the control and actuator module, we regulate the electrical voltage signal, including transforming, gaining, and filtering, to meet the requirement of sampling. We convert -5V~5V differential voltage to 0~5V single-end voltage.

3.2.2 Sampling sub-module

The sampling sub-module samples the signal exported from sub-module of regulating analog signals and the rotate speed signal of stepper motor measured by gyroscope.

The hardware of this sub-module consists of a MCU (AT89C52) and an analog-to-digital converter (ADC0809).The system employs the mean of extending RAM for communicating between MCU and ADC. The system uses the pin P0.0-P0.7 of AT89C52 as the input port for sampled value, reuses P0.0~P0.2 as address selective bit of sampling channel, and uses P2.3 as address bit. The pin $\overline{WR}$ of AT89C52 controls the write control pin ALE、START of ADC0809;The pin $\overline{RD}$ of AT89C52 controls the read control pin OE of ADC0809;The pin EOC of ADC0809 triggers the pin $\overline{INT0}$ of AT89C52. The clock signal of ADC0809 is generated by frequency division of the pin ALE of AT89C52 by T trigger composed of 74LS74.The positive reference voltage of

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ADC0809 supplied by LM336-5 is +5V.The negative reference is 0.The power of ADC0809 is supplied by external switch power stabilized by LM7805 [2].

3.2.3Actuator and sensor sub-module

The system employs hybrid two phase stepper motor Kinco2S56Q02054 to simulate yaw velocity, and gyroscope EWTS82 to measure the rotate speed of stepper motor [3]. The system controls the frequency of square wave pulses and the rotate direction to control the motion of the stepper motor. Employ Timer 0 of MCU for hardware timer, and base on it to generate software timer 0. According to sampled value, regulate the timing length of software timer 0 to control the rotate speed of stepper motor.

4 Software design

4.1 Software design of control and actuator module

As mentioned in hardware design of control and actuator module, this module will sample the signal exported from sub-module of regulating analog signals and the rotate speed signal of stepper motor measured by gyroscope, and control the motion of stepper motor.

4.1.1 The sampling programs based on Interrupt Service Routine

Because the sampling is performed periodically, it's easy to achieve by timer interrupt. The following is the structure of the program:

```
void main ()
{
    init ();        /* Initialization*/
    start ();       /*Start timer*/
    run ();
}
```

Function run () is the primary part of the control system, but in fact it's an endless loop

```
void run (void)
{
  While (1);
}
```

4.1.2 Open-loop control of stepper motor based on RTS51 operating system

The following programs control the rotate speed of stepper motor:

```
#define MOTOR_ADJ       2            //macro definition
#define PULSE_CREATE        3            //macro definition
unsigned int nTicks ;
void motorAdj (void)      _task_ MOTOR_ADJ
{
  os_create_task(PULSE_CREATE);   //create the task of generating square wave pulses
  While (1)
  {
```

```
        os_wait(K_SIG, 0 ,0);              //wait for sampling finished
         nTicks = motorOpenCtrl(smpSimuRslt);      //the function of open-loop control
    }
}
```

4.2 Software design of monitor and communication module

In the monitor and communication module, PC serves as operating console for communicating with MCU based on RS-232-C.On the PC, MATLAB is the environment for serial communication. In the MCU, the way of serial communication is interrupt. So, the flow chart of the whole system is shown in FIGURE 2.

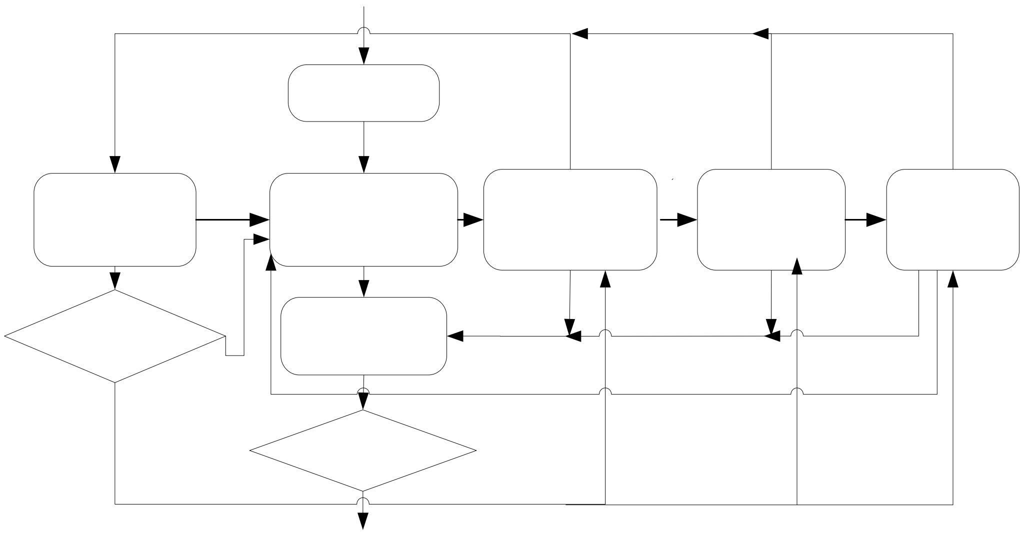

Fig.2 The Flow Chart of The Whole System

5 Steady and Dynamic test

Steady performance test can test the linearity between the driving simulator's sampled value and the gyroscope sensor's sampled value. Dynamic performance test can test the system's real-time response when the outside input values are given.

Steady performance test plot is given in FIGURE 3 and Dynamic performance test plot is given in FIGURE 4.The Y-axis, X-axis in FIGURE 3 and Y-axis in FIGURE 4 express the digital value

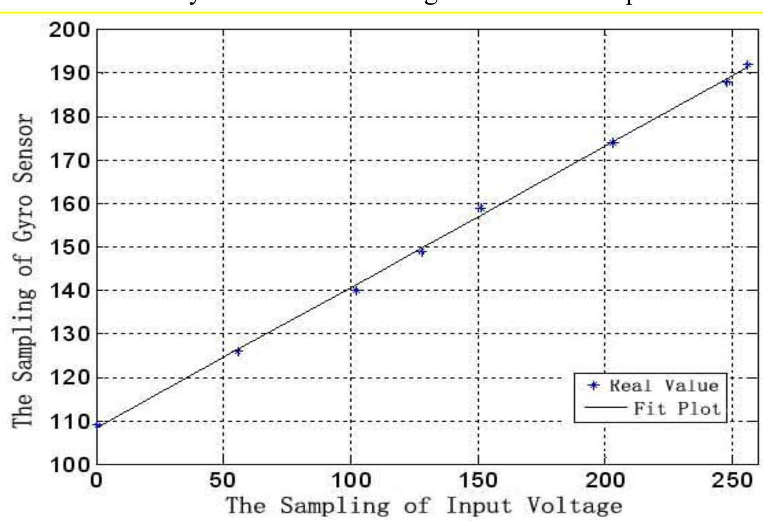

Fig. 3 Curves of Steady Test

corresponded to the analog voltage. The corresponding relationship is the range of voltage 0～5V to the range of digital value 0～255.

FIGURE 3 and FIGURE 4 prove that the system has high quality of linearity and responds fast.

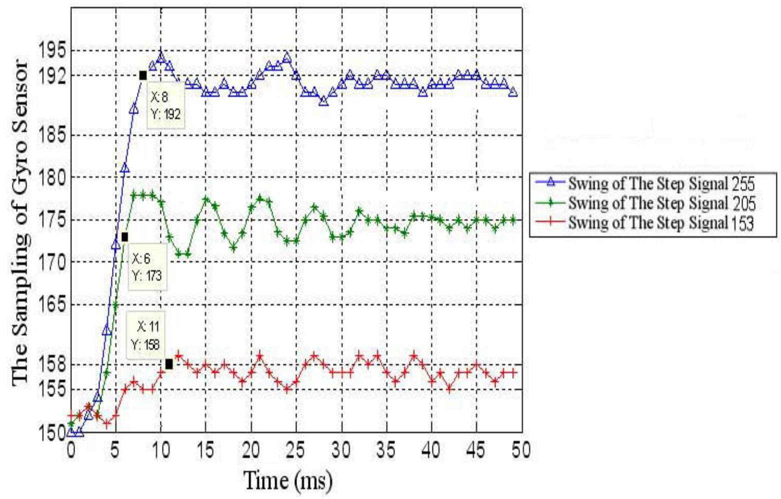

Fig. 4 Curves of Dynamic Test

6 Conclusions

This paper designs a preliminary architecture of hardware-in-the-loop simulation (HILS) system applied to yaw velocity based on ADSL driving simulator. This system can use as the test bench of the ECU of controlling yaw velocity. The result of steady and dynamic analyze prove that the system has high quality of linearity and responds fast.

7 References

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