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To cite this article: Weixin Zhang *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **252** 022126

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The 3D-simulation design of interactive action based on the magnetoresistive sensor

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Abstract. The project based on virtual maintenance technology is derived from the virtual maintenance platform of weapon equipment, and designed action acquisition module which used the magneto resistive sensor to collect body movements condition from the training person. The body movements condition was transmitted to the 3d view field of the upper machine, and then drived the virtual character to do what the the training person did synchronously. Model of body movements, program framework of the sync action between virtual and real, and the design of ant geomagnetic interference by the module of magneto resistive sensor are given by Orger engine in the 3d view field. The resultes of application displays that the design realized target demand of real-time interactive between virtual and real, and the design has characteristics as stable circuit response, accurate transmission and good anti-interference.

1. Overview

In the development of a kind of simulation training system, it is required that 3D field of view simulation can provide visual effect fluently and real-time in Ethernet. The state of limb movement of the trainer is accurately captured into the 3D visual field in the real time. The developer uses the self-designed FPGA core circuit to build the limb motion data acquisition together with the magneto resistive sensor and the gravity acceleration sensor. The 3D image field of view that is developed with Orger engine is mainly completed by 3DMax. The hardware of the model platform is composed of limb action acquisition module, core circuit board, 3D glasses and visual simulation computer and so on. The structure is shown as Fig. 1

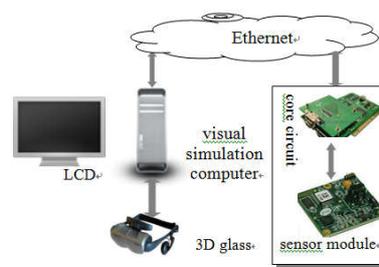


Fig. 1 Hardware structure diagram



The simulation training system is mainly used to collect the real-time information of limb movement in the interior limited space and accurately reproduce the information in 3D field of view. The information of limb movement is mainly obtained by two sensor modules sensing angle change, the real-time state of which is sent to the core circuit board FPGA through SPI serial communication. The data which is passed by the core circuit board to the visual simulation computer through the Ethernet gigabit switch is synchronized in form of three-dimensional virtual way in 3D glasses under the control of the 3D engine.

2. Hardware design

2.1. FPGA core circuit

The hardware circuit mainly includes power module, Ethernet communication module, limb action acquisition module and XC3S700AN chip as the core of the FPGA circuit, mainly responsible for communication with the sensor module circuit and transmission of the limb action information to the field of view simulation computer. The data communication based on SPI protocol between the core circuit and the sensor module, and the communication with computers or other extensible devices through the construction of Ethernet is shown as Fig. 2

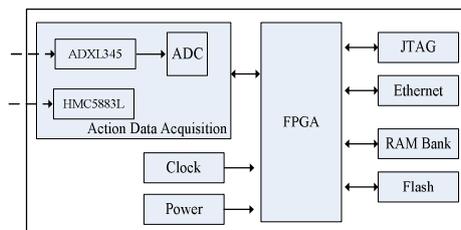


Fig. 2 Schematic diagram of core circuit

The FPGA circuit includes the following functional module: FPGA core module, limb action acquisition circuit module, Power adapter module, clock crystal module, Ethernet driver circuit module, JTAG debugging module and peripheral interface module.

2.2. Acquisition circuit from body movement

The acquisition circuit of limb action is composed of acquisition module sensing changing azimuth angle and tilt angle of the action and interface synchronous data communication module in the 3D of view [1]. It is the precise measurement of the 1° resolution information which sent to 3D field of view software in the upper machine via after encoding and decoding. It can achieve synchronization effect of virtual model and external physical action changes in the 3D field of view through the rapid data interaction of attitude angle and the 3D field of view software.

In the aspect of mechanical structure design, considering the rotate when cable winding, magnetic resistance sensor led datum error increases and undamped movement, using conductive slip ring SNM022A build the base of the data acquisition circuit. It is considering that the cable winding and the rotation of the magneto resistive sensor results in the increase of the reference point error and the undamped motion. The base of the action data acquisition circuit is constructed by using the conductive slip ring SNM022A. The motion data acquisition circuit can be bound to the surface of the action limb and the conduction slip ring stator output terminal is connected to the core circuit. SNM022A is a 24-way cap type conductive sliding ring for connecting the signal between the upper bearing rotator and the lower signals, to ensure that the wire will not rotate in the upper part of the wire.

To overcome the interference of geomagnetic and surrounding magnetic fields to the sensor, the PTFE material is used to make the fixed partition between the data acquisition circuit and the

conductive slip ring, which can prevent the geomagnetic interference of the circuit module fixed in the inner part.

The multi-sensor integrated module is the input interface device for interactive 3D field of view simulation. The precision of magneto resistive sensor and the index of anti-interference will affect the precision of data acquisition. Real time state of azimuth measurement of HMC5883L sensor chip based on platform [2], select three-axis gravity acceleration sensor ADXL345 to measure the real time state of the tilt angle of the action[3].Honeywell three-axis magneto resistive sensor has a drive circuit built in and does not need to be designed separately, coupled with five fine long gauss detection resolution, the attitude angle of horizontal rotation acquisition is accurate to 1 °. The measurement accuracy of ADXL345 with 13-bit digital resolution is more precise and its sensitive information is output to the core circuit in SPI format through the 4-line signal line.

After the geomagnetic change is collected by the sensor, the sensitivity of the horizontal magneto resistive element in X and Y directions is obtained by the magneto resistive sensor chip, and the corresponding voltage variation is obtained along the axis. The differential voltage is transformed into a differential voltage via its SDA port in the direction of each axis, and then is sent to the core circuit through the conductive slip ring. At the same time, the acceleration sensor chip acquires the geomagnetic change data. The tilt change information is processed by analog-to-digital conversion and filtering, and the corresponding 8bit elevation angle variation data is output through the bi-directional SDA port. Through conductive slip ring to the core circuit. Two sensors attitude angle acquisition circuit as shown as Fig. 3

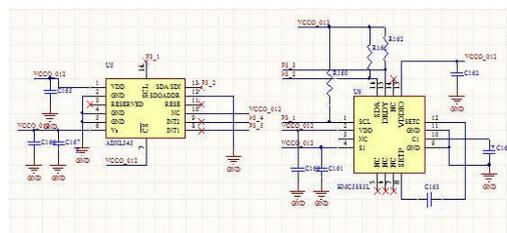


Fig. 3 Sensor action attitude Angle acquisition circuit

2.3. Power module circuit

The power of FPGA core circuit is supplied by the core VCCINT, Bank power supply VCCO and auxiliary power supply VCCAUX. For Spartan-3 series FPGA kernel voltage is fixed 1.2 V. Each I/O Bank voltage is 3.3 V. Auxiliary voltage is supplied to JTAG test pins or other special-purpose configuration pins. The voltage is fixed at 2.5 V, the indigenous power management chip LP3906 is used in the field measurement. The external input power supply is supplied by a 5V power supply module and the maximum power supply current is 4.7A by circuit optimization. The interior of LP3906 integrates two dynamic voltage management converters, two 300mA linear regulators and an I²C bus controller operating at 400kHz. It can adjust the output linear voltage in the range of 1.0 V to 3.5V. The power module circuit is designed using LP3906 shown as Fig.4, whose 5V power supply is input through the J6 connector. D11 is the power input indicator lamp, 5V electricity is sent to LP3906 after double safety filter of capacitance C4C5 and C12C13[4]. After the linear adjustment of the I²C bus controller, 3.3V electricity is output from the interface SDA and SCL for the use of FPGA Bank0 Banc1 and Bank2.

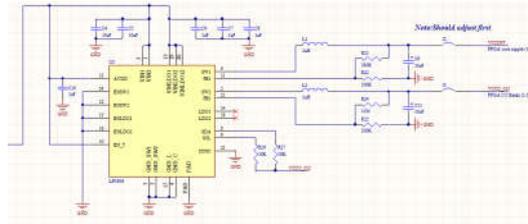


Fig. 4 Power module circuit

2.4. Ethernet drive circuit

The FPGA core circuit board transmits the collected limb motion change data to the visual simulation computer through the Ethernet switch. Under the control of 3D engine, the information is synchronized in 3D glasses in 3D form. In view of the advantages of fast transmission rate, remote transmission distance, simple networking and good reliability, the simulation system uses Ethernet to communicate data between devices.

In the Ethernet driver module, the LAN8700 chip is controlled by FPGA to work in MII mode. At 100 megabit transmission speed, the interactive information in the simulation system is transmitted via Ethernet network after encapsulating and packaging. After comparing the advantages and disadvantages of TCP and UDP, the UDP protocol suitable for simulation system is adopted for data transmission, and the maximum length of the UDP Datagram is defined according to the length range of the ethernet data frame. As a single-chip Ethernet physical layer transceiver, LAN8700-AEZG supports that media independent interface can choose PHY working rate (10 Mbps / 100 Mbps) and set PHY working mode (full duplex or half duplex)[5].

In the interactive Ethernet, it is also necessary to connect the visual simulation computer and the switch through the RJ45 interface, in order to ensure the transmission distance and the integrity of the transmission signal of Ethernet. A network transformer HR911110C connected to PHY is added between LAN8700 and RJ45 interface, the transmission operation indicator of which is under the control of the LED circuit module of LAN8700 to indicate the running state of network information. The high-speed Ethernet transceiver gateway is constructed by using the LAN8700 automatic reverse control module (auto-mdix) and the transformer module in the network transformer. In the circuit design, it is necessary to pay attention to the design of the differential signal circuit for data signal T+, T-, R+ and R- transmission in full duplex mode [6], to reduce external interference. The design of Ethernet drive circuit is shown as Fig. 5

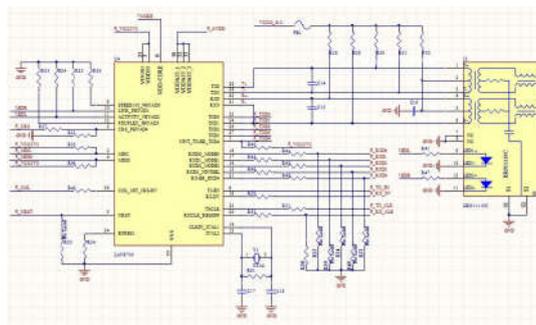


Fig. 5 Ethernet drive circuit

3. The software

The 3D visual field simulation software mainly provides the 3D simulation effect of the field of view and an operating environment for the simulation training platform. The structure of the software is shown as Fig.6, mainly including: interface communication module, data processing module, user interface module, model base, simulation control module.

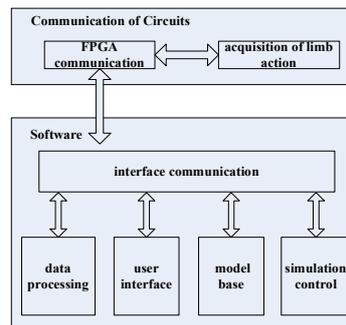


Fig. 6 System software structure diagram

The data transmitted by Ethernet is received by the interface communication module, and then sent to the user interface module and the external response device for state response after the correlation operation processing of the data processing module. The user interface module calls and executes the program, and finally updates the human-computer interface of the simulation system. The function of the simulation control module mainly includes the call of the limb action instruction, the operation of the model, the comparison of the actual action and the simulation action, and the anti-interference treatment. As the limit of the length and the structure design of hardware, the software part mainly explains the modeling of body action in 3D field of view, how to synchronize to 3D field of view after sampling circuit collecting the angle information and how to design georesistive sensor module to resist geomagnetic interference.

3.1. Modeling of body movements

When the limb movement changes, the sensor module notifies the FPGA of the sensitive level and pitch angle change information. FPGA packaged the information and sent it to the visual simulation computer according to the UDP protocol, and controlled the limb motion model to synchronize with the real motion according to the angle variation [7]. The 3D field of view simulation model is developed by adding 3D model library to the object-oriented graphics rendering engine Ogre. Ogre(Object-Oriented Graphics Rendering engine is an open source 3D engine developed in C language, using some classes of Ogre can be used to interconnect with QT. The virtual action model is modeled in 3D, which is the same as the static and dynamic structure of real action.

First, the base class of Model is created, which contains the position, azimuth and rotation orientation functions for the new addition for the base setup of the new model. Then a new device class, ZT device, which inherits from Model, defines the scene management, audio properties, device number and position coordinates for creating the model. You also need to create the Ogre interface class MyOgre Widget in QT to add initializing grooves and rotation-oriented grooves for limb actions in Ogre. The concepts of global model node (master node) and rotational partial node (sub-node) are introduced in order to realize the phased control of different rotational velocities of joints. In this way, the global model with inconsistent local motion can be coordinated and controlled.

3.2. Interface communication

Through the base class member function setPositon (), set Direction () and set Orientation (), the coordinates of th model were respectively set up in the scene coordinate, azimuth and initialize the front. The structure pointer of the master node and the child node, azimuth member function is realized by creating a new ZTDev device class, which is inherited from the base class for the number of limb actions.

Then, the construction function ZTDev() is used to manage the scene, and the 3D model and quantity, control sub-node and view point are created, and the location of the child node and the viewpoint is set.

Finally, the slot function `init ZTDev_slot()` creates an initialization of action location and quantity, and the slot function `set ZTDev_slot()` to set the orientation. And a link to the external event response output is established. When the virtual model of limb action is added, it is necessary to establish a channel to receive the rotation attitude information sent by FPGA.

The link to the external event response is built by receiving member function of the thread Receive Thread and writing the internal programming model socket `mapRevSetSocket`.

The program should not only realize the function of creating the receiving data channel, but also has the function of interface information recognition. Finally, the limb level and pitch rotation angle value sent by UDP and the components in horizontal and vertical directions are received through the slot function receive datagrams `Slot slotted`.

3.3. Anti-geomagnetic interference algorithm

Because the external magnetism is easy to interfere with the magneto resistive sensor, the hard magnetic and soft magnetic effects are obvious[8]. The soft magnetic correction is complicated and requires a large amount of real time sampling. This paper illustrates the method of hard magnetic correction with an example.

After the data acquisition circuit is fixed in position, rotate 360 degrees at a constant speed, receive X and Y coordinate data, and repeatedly acquire the sample size. The maximum and minimum values of the data are analyzed, and the coordinate offset of the hard magnetic influence is calculated as $X0=(Xmax+Xmin)/2$, $Y0=(Ymax+Ymin)/2$, $(X0,Y0)$ is moved to the origin of the coordinate. Because it is a hard magnetic phenomenon, the obtained pattern is approximately, without the modification of X and Y.

It should be noted that due to the high sensitive accuracy of the magnetic material and different offset of the position of the data acquisition circuit, the data obtained by the same data acquisition circuit using different sensors also has small differences. Therefore, the data acquisition circuit is rebound, a signal acquisition is required, and the offset is calculated.

4. Summarizes

The simulation effect of limb action in 3D field of view is shown as Fig.7. The simulation model of limb action is represented by monobloc after the project content being descanned.

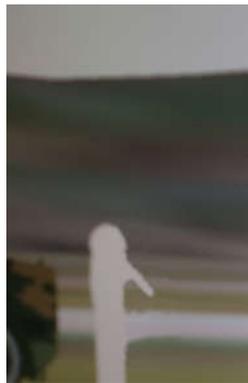


Fig. 7 Simulation effect diagram

In the process of integrating the 3D simulation model of limb movement into the virtual maintenance platform of large weapon system, the amount of data transferred in the network will increase large when the limb moves rotate rapidly. Occasionally there will be a stall phenomenon when the action of the 3D simulation model and the actual limb match. The next step is to further the communication design of the underlying circuit and the host computer.

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