Development of firefighting training clothes based on embedded wireless sensors

Mengmeng Wang, Fangjie Yu*, Rui Jang,Shengbo Ma,Yang Zhao

Ocean University of China, QingDao, 266100, China

Keywords: Human-computer interaction, multi-sensor, firefighting training clothes, wifi, temperature control.

Abstract. This paper has described a firefighting training clothes based on embedded wireless sensors which provides the wearer with multi-mode human-computer interaction. The whole software system is made up of four single modules: temperature data acquisition module, motion data acquisition module, data communication module, temperature control module. When wearer moves in the real world, the accelerometer and the gyro can measure the wearer's movement information so that the virtual character in the virtual scene walks the same path as the real one. Command will be sent to the heating and cooling modules in order to adjust the temperature of the firefighting training clothes while the virtual character is close to or away from the fire source. We designed experiments to test the temperature control function of firefighting training clothes in certain circumstance. The results showed that the wearer could tell the temperature change when the virtual character is close to or away from the fire source. In the future, we plan to provide the wearer with immersive interactive experience via virtual reality helmet so that the wearer can be fully integrated into the virtual scene.

Introduction

The development of human-computer interaction technology[1,2] has been very quickly, and the machine information inputting methods grow with that, for example, keyboard input, touch input, voice recognition, gesture recognition. At the same time, there are multiple ways of information output, and the possible ways of information output are auditory sense, visual sense[3], tactile sense, olfactory sense. Above auditory and visual sense are the most common ways, while tactile and olfactory sense are barely used nowadays. This paper describes the use of embedded technology combined with virtual reality, which adds tactile on the basis of visual and auditory sense making the human-computer interaction more comprehensive. It is so intentional to conduct research on multi-channel human-computer interaction that human can get more information while interacting with computers. Currently, on the one hand, most of the firefighting training clothes is concentrated on obtaining the human condition and the surrounding environmental data by the use of multi-sensor. The combination of firefighting training clothes with temperature feedback and virtual scene have not found yet to be applied in firefighting training. On the other hand, virtual scene and firefighting training clothes are not combined perfectly because the system did not offer the corresponding temperature feedback of the virtual scene. The problem that body temperature is not relate to the virtual scene makes wearer feel unreal so the wearer can’t get more emotional experience by using this system.

In daily life, fire is very dangerous but rare to see. As a part of the whole system, firefighting training clothes will be an efficient assistant tool to combine the virtual scene and realistic temperature feeling which helps the wearer to experience the firefighting process without any danger at all. Most virtual firefighting training systems offer wearer the fire feeling only in the visual and auditory way, so it is not perfect in interaction experience. It is a trend to add more sensors on clothes or any other wearable devices so as to acquire the data of wearer as much as possible.[4,5] Through multi-sensor synergy to obtain the wearer's motion data[6], virtual character can be controlled by the wearer. In this way the wearer can get the real experience. A team led by Per Backlund[7] has developed a virtual fire training system based on virtual reality technology, which provides the participants with immersive fire scene. However, there is no temperature control

of the firefighting training clothes in this system, so participants is impressed by the effect of the visual and auditory system while receiving no temperature feedback from the virtual fire scene. Moohyun Cha's[8] team has combined the virtual firefighting training system with fire dynamics data which makes effect of the virtual system much more real whether in visual or auditory sense. But the same defect exits here is that it does not offer participants the temperature feedback as well.

In the firefighting training system, we mainly focused on the implement of the firefighting training clothes. In our interaction temperature control system of the clothes, temperature control module consists of semiconductor heating bands and efficient cooling fans. Heating and cooling module can quickly heat or cool the firefighting training clothes, which allows the wearer feeling temperature up or down in a short time to achieve a better effect. Miniature temperature sensor is used to measuring the wearer's body temperature while accelerometer and gyro can detect the wearer's movements[9,10]. Both the temperature and the wearer's motion data are processed in the STM32F4MCU[11,12] then sent to virtual scene through wireless wifi module[13,14]. The virtual characters are controlled according to the wearer's motion data. The virtual scene system based on OpenGL standard graphics library combines with the data provided by the multi-sensor makes the interaction between wearer and virtual scene more intuitive, convenient. Besides the firefighting training clothes uses the miniature sensors to reduce the volume and quality. To reduce system power consumption, the power distribution has been rationally managed. All those efforts above make our clothes more convenient and prolong its battery life. What's more, the software system running on the STM32F4MCU is based on the C language to make sure the implement of all functions. Software system is designed modularly so that each module of the system is independent and not affected by each other. It facilitate the maintenance and expansion late as well. According to the experimental data, the firefighting training clothes can make the correct response to changes in the simulated environment. The temperature is up when the virtual character is close to fire source and down when the virtual character away from fire source.

Firefighting training clothes hardware system

Hardware system consists of temperature control module, temperature sensor module, accelerometer and gyro module, wireless wifi module and power control unit. Temperature control module is made up of semiconductor heater bands and efficient cooling fans so as to adjust the temperature quickly. The temperature sensor module is to obtain the temperature of clothes. The accelerometer and gyro module is to get the motion data of the wearer. The wireless wifi module can send the temperature and motion data to the computer in order to avoid the cable connection between PC and firefighting training clothes and then the wearer's movement will not be affected by the cable. Meanwhile, to make sure the safety of the wearer, the clothes' temperature is detected in real time for fear of any accident caused by the heating bands.

As an extension, one PC can connect to more than one firefighting training clothes. In this way, the hardware resources can be fully used. Besides, all the firefighting training clothes are able to be monitored at the same time and all the data can be processed together to make the management more convenient.

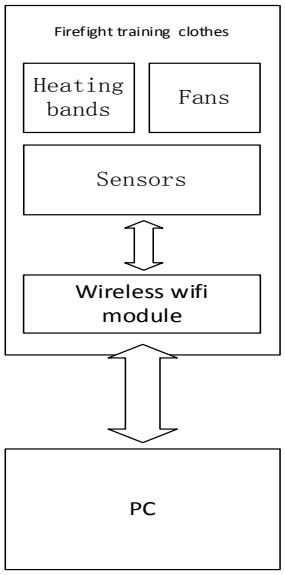

Fig. 1:The hardware system of firefighting training clothes

Software system

There are two major parts of the software system, the embedded software system of the firefighting training clothes and the virtual firefighting training system. Our job here is mainly focused on the embedded software system. The embedded software system is designed to achieve functions like temperature control, wireless data transmission, real-time temperature monitoring, real-time motion data acquisition. Developing tool for the embedded software system is Keil5.0 and the source files of the project includes four modules: temperature data acquisition module, motion data acquisition module, data communication module, temperature control module.

The main function of the temperature data acquisition module is to set up initialization of temperature sensor and obtains the wearer's temperature data. Besides, data format conversion and data packing process are included in this module as well. This module contains initialization function, temperature data acquisition function, data format converted function, data packed function et al. Motion data acquisition module is used to do the initialization of accelerometer and gyro and then gets the motion data of the wearer. Before packing these data, data format should be converted first. This module contains initialization function, motion data acquisition function, data format converted function et al. The main function of data communication module is to transport data between firefighting training clothes and PC, so wifi connection function is required in the PC. In this module, the initialization is set up first and then gain the wearer's motion data. In addition, the data is checked to make sure the correctness of data transmission. Command receiving is included in this module as well. This module contains initialization function, data transmission function, data receiver function, command analytic function, data check function. Temperature control module controls the temperature of the clothes according to the wearer's motion data. This module contains heating function, cooling function, motion analytic function. Motion analytic function is to get the movement of the wearer by calculating the motion data. Besides, the function main is included in the source files. The initialization of clock and interruption of system are done here.

Result and discussion

The device used in this study is the ASUS personal computer which runs the windows 8.1 OS. In the virtual scene, the type of fire can be chosen and adjusted in order to meet the need of different training programs. Virtual character in the scene can move freely according to motion of the wearer. The body temperature of the wearer is displayed in the right top of the scene and stored in the database automatically.

A simple experiment was designed and implemented to verify the effect of temperature control of the firefighting training clothes. The temperature of two different situations were measured in the same conditions (skin: 35C). When the virtual character got close to the fire source, the temperature of the clothes was measured at the same time. In contrast, when the virtual character got away from the fire source, the temperature was measured as well. The results are shown in fig5.

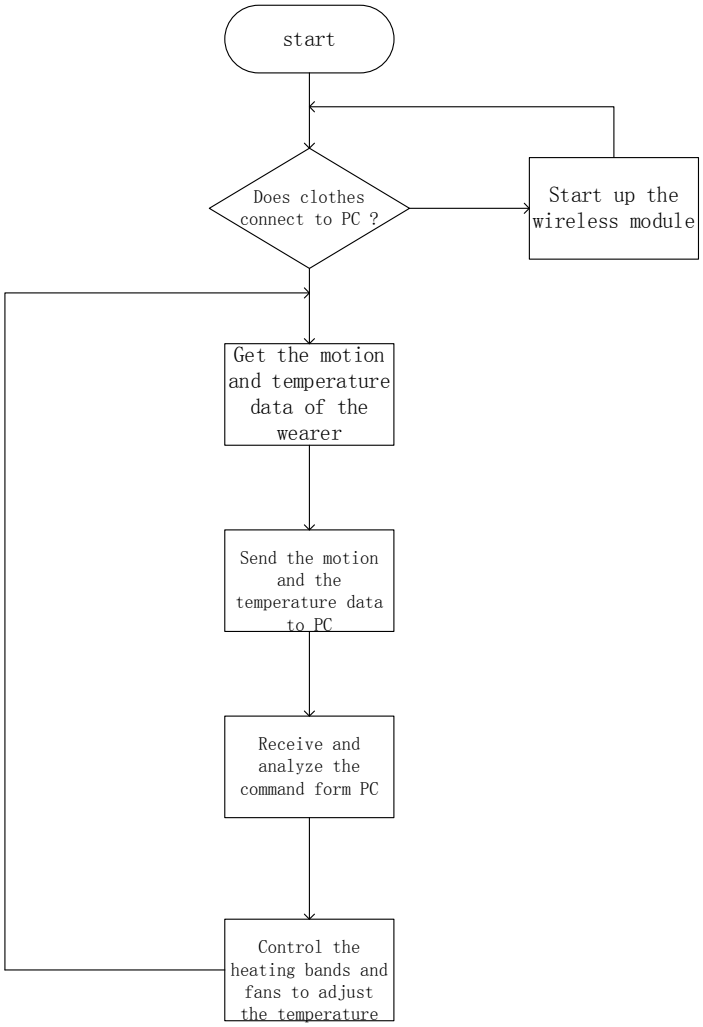

Fig. 2: The flowchart of software system

Fig.3: The virtual character is close to the fire source

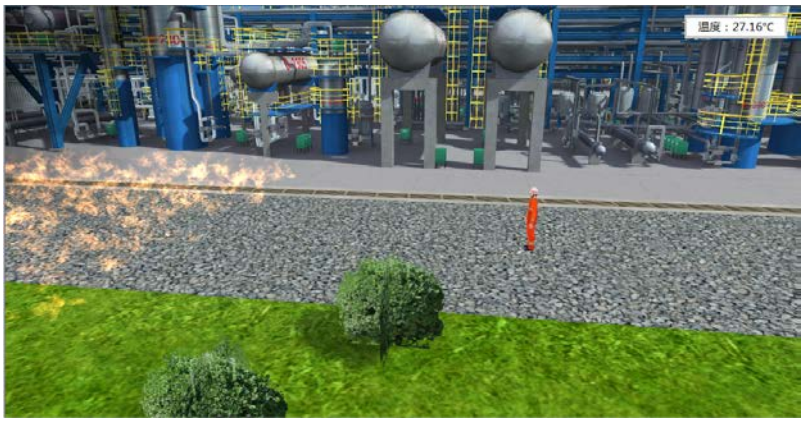

Fig. 4: The virtual character is away from the fire source

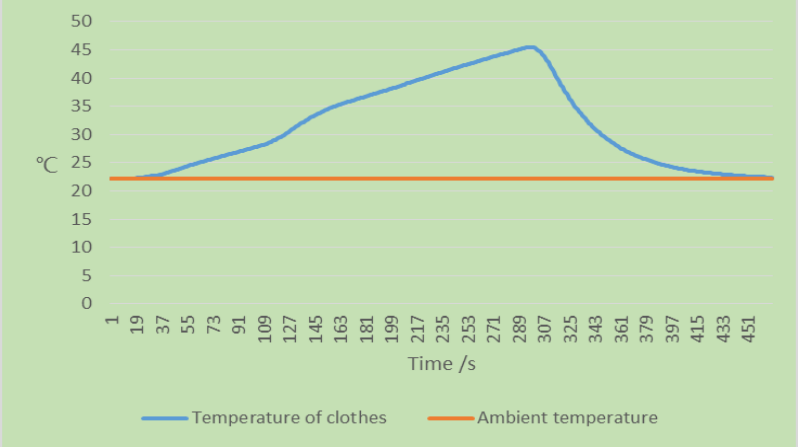

Fig. 2:The experimental results

Conclusions

With the development of technology, some other methods like feel, smell, taste et al will be used to make interaction between human and computer more vivid so that you will not tell which is real. Today it is just a little step to be closer to that target. In this paper we develop a firefighting training clothes based on embedded and wireless technology, and a simple experiment was executed to verify the feasibility. This virtual scene system receives temperature and motion data from the wearer via wifi and provides a corresponding reaction to the motion command. The temperature of the clothes can be flexibly controlled according to the virtual scene. In all, the interface provides real-time audible, sensate and visual feedback for the wearer.

Future work will focus on remote control-a web based information system which can monitor and ensure that the data of the firefighting training clothes can be seen at anywhere anytime. Besides, we also plan to replace the PC with a virtual reality helmet to provide a flexible visual scene to the wearer.

Acknowledgements

The research work was supported by 2014 Qingdao science and technology projects of applying basic research for young under Grant No. 14-2-4-92-jch.

References

[1] Alejandro Jaimes, Nicu Sebe. Multimodal human–computer interaction: A survey. Computer Vision and Image Understanding 108 (2007) 116–134.

[2] Achim Ebert • Nahum, D. Gershon •Gerrit et al.: Human-Computer Interaction Introduction and Overview.Springer-Verlag Künstl Intell (2012) 26:121–126.

[3] A. Adjoudani, C. Benoit, On the integration of auditory and visual parameters in an HMM-based ASR, in: D. Stork, M. Hennecke (Eds.), Speech Reading by Humans and Machines, Springer, Berlin, NY, 1996.
[4] Mehmet Engin, Alparslan Demirel et al.: Recent developments and trends in biomedical sensors. Measurement 37 (2005) 173–188.
[5] Hadi Banaee, Mobyen Uddin Ahmed et al.: Data Mining for Wearable Sensors in Health Monitoring Systems: A Review of Recent Trends and Challenges. Sensors 2013, 13(12), 17472-17500.
[6] Shaopeng Liu, Robert X. Gao et al.: Multisensor Data Fusion for Physical Activity Assessment. IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 59, NO. 3, MARCH 2012.
[7] Per Backlund, Cecilia Hammar et al.: Sidh – a Game Based Firefighter Training Simulation. Computer Society 11th International Conference Information Visualization (IV'07)0-7695-2900-3/07.
[8] Moohyun Cha, Soonhung Han et al.: A virtual reality based fire training simulator integrated with fire dynamics data. Fire Safety Journal 50 (2012) 12–24.
[9] Chang- Ming Yang, Tsu-Lin Yang, Wen-Tzeng Huang , Chin-Hsing Chen,Shu- Hui Hung, Chih-Ming Cheng, Mu-Huo Cheng, “A NovelDesign and Evaluation of Wearable Digital Sensor for Monitoring Posture”,EEC EMBC 2008.
[10] Hansong Zeng , Yi Zhao.: Sensing Movement: Microsensors for Body Motion Measurement. Sensors 2011, 11(1), 638-660.
[11] Anonymous. Arm directives - using as. http://sourceware.org/binutils/docs/as/ARM-Directives.html, jul2012.
[12] Blog, E. E. Stm32f4 discovery usart example. http://torrentula.to.funpic.de/2012/05/20/stm32f4-discovery-usart-example/, jul2012.
[13] Li Li, Hu Xiaoguang et al.: The Applications Of WiFi-based Wireless Sensor Network In Internet Of Things And Smart Grid. 2011 6th IEEE Conference on Industrial Electronics and Applications, 21-23 June 2011, 789 – 793.
[14] Wu Hao, “Internet of Things wireless mobile communication and application analysis”,Computer Knowledge and Technology, July 2010,Vol.6, pp.5205-5206.