Head Mounted Wind

S. Cardin
VRLab - EPFL
sylvain.cardin@epfl.ch

F. Vexo
VRLab - EPFL
frederic.vexo@epfl.ch

D. Thalmann
VRLab -EPFL
daniel.thalmann@epfl.ch

Abstract

Within the context of tele-presence and immersion for piloting light aircraft, knowledge about the surrounding wind offers useful information for piloting purposes. Rendering wind in virtual simulation or tele-presence application has been used still the early sixties [1] to enhance immersion. However since then it has been rather limited to use a fan in front of the user to produce an illusion of speed. This paper presents the development of a new haptic device generating wind around the user head. The system is based on an embedded system driving 8 fan actuators regularly distributed around a Head Mounted Display (HMD). In order to validate the added value of the device in the context of tele-operation, an application has been developed around a flight simulator where wind direction and forces are passed to the user via our system. Feedback from the different users of the applications shows improvements of the immersion inside the simulation. It also gives reliable information about the wind direction and forces using the most natural cues.

Keywords: Head Mounted Wind, Immersion, Virtual Reality, Tele-operation.

1. Introduction

Flying light aircrafts, such as glider, blimp or a Unmanned Aerial Vehicles (UAV), becomes uneasy while they are under local wind perturbation. According to research done for autonomous based methods done by J.M. Pflimlin and al. at the NASA ames research Center [2], the wind is a critical parameter to handle. The main issue in tele-operation applications is that the pilot has no way of knowing the direction and forces of the wind at the position of the vehicle. Most of the corrective control is done to counter act the effect of the wind on the position. The wind is perceived indirectly by its effect on the aircraft. In the research done by M. Quigley and al. at the University of Provo [3] about UAV surveillance system control, it shows the influence of the wind on the trajectories to maintain a given trajectory. . The wind has dramatic effect when it rises 75% of the airspeed of the aircraft.

In previous work done by X.Rigetti and al [4], they have developed a tele-surveillance application using a remote controlled blimp. In early testing they encountered issues in piloting the remote blimp around various building. The wind at the passing of building’s edges was changing drastically and induced tremendous deviation in the aircraft course. In order to collect information about this effect to the distant pilot, a set of relative pressure sensor were scattered around the blimp. Once the wind information is measured the system sends the data through wireless communication to an embedded system on the ground which renders this information around the waist via vibrotactile cues. The whole application shows improvement of the piloting condition by adding metaphorical extra-sensorial information about the local perturbation around the aircraft.

The main objective in our case is to improve the immersion of the pilot. We propose to remove the break in presence induced by the metaphor of using vibrotactile feedback to pass wind information to user by generating real wind around the user head. He is able to feel the wind as if he was onboard the aircraft. Our goal is to extend this principle to create a generic haptic device able to simulate wind for different type of application with the objective of improving immersion of the user into the virtual worlds or the presence of distant objects.
This paper will present first a set of related work to the problematic of wind representation and their use in virtual environments. Then we will describe our solution and the working principle of our system. The following part will present the detail software and hardware architecture. We will present also the tests and results obtain within our specific application. We will finish by a technical conclusion opening to further works in the domain.

2. Related work

Improvement of immersion and presence is a major theme of research in Virtual Reality. According to C. Heeter [5], Presence can be defined by the sense of being there and can be characterize in two main aspect. The social presence is the aspect covers by the cue that make yourself exist in the Virtual environment by its reaction to your presence and actions. The second aspect is the personal presence which makes you feel that you are in the virtual environment. This personal presence aspect covers the main area of research. It covers realistic rendering for real time graphics, auditory enhanced and tactile feed back. Odors are also synthesized in some particular application. Researches in this field are growing since now fifty years, In 1955 M.L: Heilig, a film producer, presented is view of the future of the cinema [1] which includes stimulation of the different human senses. He realized a single person prototype in 1961 called sensorama offering a simulation of images, sounds, smells and wind.
Tactile feedback is one of the most challenging subjects in the area of virtual reality. Various haptic systems have been developed those last decades from mechanical arm for force feedback, to vibrotactile system, via temperature actuators or even tactile display for the tip of the finger.
Representation of wind information in virtual reality application isn't a really popular subject. Although fully immersive application has been developed to present detail wind flow in a scientific visualization manner as the famous application of the wind tunnel developed at the NASA Ames Research Center in 1992 [6]. In this application the user is fully immersed in a virtual wind tunnel to characterize aerodynamics properties of a prototype aircraft. Since the application aims at visualizing precisely the airflows it represents them as graphical line. The immersion is in this case is mostly oriented around 3D rendering allowing the users to turn around the scene using a position tracked HMD.
However wind actuators as using a big fan is a rather classical cross modality in ride simulators. Immersive movies using motion platform, as can be found in funfairs, often includes a powerful fan in front of the screen to pass speed information to the user. Such system increases greatly the sense of being inside the movie which usually consists in racing, roller coaster or downhill skiing simulation. Even if this system is truly immersive, it is slightly outside the field of virtual reality since the user is totally passive. Some application closer to virtual reality however uses the same techniques to render speed information. The research done on the virtual scooter developed in collaboration with the tufts University and the University of Georgia [7] is one good example. This training application about urban scooter driving uses multimodal feedback to immerse the user into the virtual environment. The user is driving a virtual scooter using a minimal mockup. He's wearing a mounted display which renders stereographic visualization of the environment. The speed of the scooter is render using a fan. In this case also the system can only rendered the wind in half a degree of freedom. Only the forward wind can be rendered.
Research done at the Fraunhofer Institute for Computer Graphics [8] offers an interesting approach for using wind as an immersive factor. The application they developed put the user in a virtual house were wind and temperature enhanced is provided. For example the user can approach the hearth of the

chimney and feel literally the hot air coming toward him. As the user turns around the air flow is produced in different location. They use small fans to generate an airflow and infrared radiant light source to produce the heat. The major interest of this application consists in using multimodal feedback for improving immersion in virtual environment.

Improving immersion with multimodal feedback, including wind actuator, is also a growing market for commercial application. The world famous company Philips just released the amBX system [9]. This system is mainly based a dynamic ambient light system and audio surround. But it also includes some tactile feedback through a vibrating rumble pad and two fans to blow winds at the user face. It shows the growing interests of the industry in this kind of technology.

Even if the use of wind for immersion has been introduced long ago to render speed, it stayed as marginal devices and hasn't been applied to many other applications. There is a lack of proper devices for render realistically the wind force and direction in virtual reality and tele-operation applications.

3. Working principle

Our goal in this development is to fill the gap between the needs of wind representation for tele-operation of UAV and the lack of available hardware, by presenting the development of a device which renders multidirectional wind on the user head.

The main idea is to fix a set of fans directly around the user head. In order to prevent limitation of the visual field the graphical feedback is given directly in front of the user eye using a Head Mounted Display (HMD). By using a sufficient number of fans we can reproduce wind feedback in every possible direction. The wind force is rendered by tuning the fan speed.

In order to render omni directional wind we fix the number of fans to 8, equally distant from each other in every direction of the user head, as shown in Figure 1.

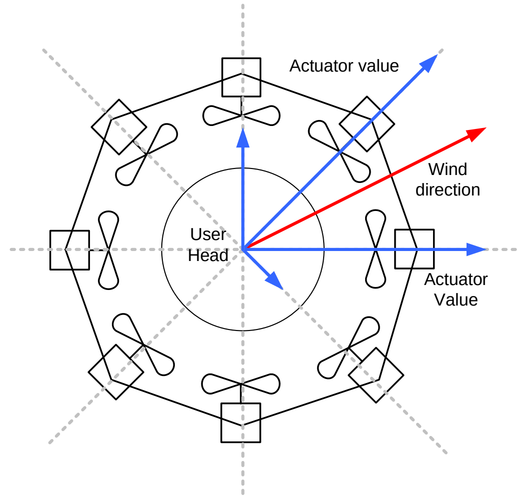

Figure 1: Wind feedback representation

The wind information is converted in a vector containing information about direction and speed. Each actuator's position around the user the user head is coded as a position vector. A simple interpolation based on a dot product of the wind vector over each position of the actuators is used to compute the contribution of the wind on each actuator value

In order to provide an application context to the use of our Head Mounted Wind system, we decided to measure the added value for piloting glider in a flight simulator. The main purpose is to test benefices in term of immersion and correctness of wind information.

4. System description

4.1 Overview

The System is composed, as shown in Figure 2 of a commercial head mounted display enhanced with our wind system driven by a microcontroller. Both the HWD and the HMW are controlled by the simulation running onto the PC.

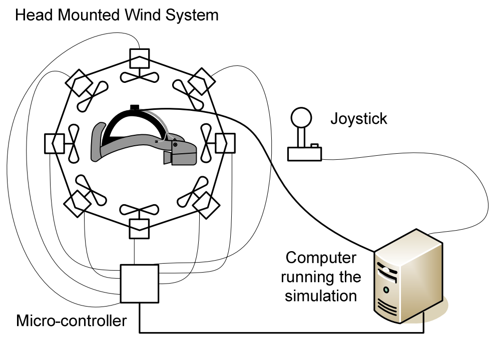

Figure 2: Overview of the system

4.2 Simulation

For rendering the virtual scenery to the user we used the HMD Kaiser in our application. It offers stereoscopic vision by displaying two slightly different images for each eye in order to pass naturally depth information.
A full immersion of the user in the virtual environment is achieves by limiting is vision field to the scene and cut visual references to the surrounding environment. Also A sensor could be use to track the orientation of the user heads. This is used to map the movement of the user to the virtual camera in the rendered scene. The effect of this system is that the user interacts naturally with the virtual environment to turn the camera in the scene. This effect increase the feeling of immersion

Figure 3: X-plane simulator

We used the commercial product X-plane for our purposes. This software is a commercial application which is used world widely for flight training purpose and certified by the Federal Aviation Administration. The user is using a standard joystick and thrusters to control the plane as in real piloting condition. It offers a high realistic flight simulation and allows external control on numerous output and input parameters over the simulation.

4.3 Software

In order to pass information from the simulator to our dedicated hardware, software has been developed to offer the following services:

Connection to the simulator:

Our system implements a UDP client which connects to the simulator by sending request about the data to be sent. It gathers the responses containing the information about the wind direction, the wind forces and the heading of the plane.
The data is gathers enclosed a proprietary UDP packets format of the x-plane simulator. The packet is traditionally composed by a header indicating the type of the message, if it’s a request, a data packet or various simulation handlers. In our case we mainly deal with request and data packets which are referenced by the index data and an array of floating point’s values containing the desired data.
One little note on the data format for communicating with X-Plane is that we should mind little endian big endian conversion since the UDP server is based on the Mac OS-X format.

Input/output correlation:

As mentioned above the system gathers the wind direction, wind force and the heading of the plane though the UDP client. The heading of the user head is gathered through serial connection to the inertia tracker fixed onto the HMD. In order to take in account the user head position we initialize the system while the user is facing the instruments.
The wind direction and wind force is given in the simulator referential. Since the goal is to present the wind in the world referential, the aircraft heading and the user head orientation are needed to transform the referential of the wind. The referential transformation is simply done by a summation of the heading of the aircraft, the wind direction and the user head orientation.
The next step is to transform the local wind information into each of the eight the actuator

values. A calibration curved adjusted by the user allow fine tuning of the correlation of the data input to the desired feedback by also getting rid of the nonlinearity of the system. This calibration curve is represented as a hamming curve with movable control points. This presents the heart of the system by computing the response to be sent to the actuators through the embedded system.

Connection to the embedded system

Once the contribution to each actuator has been computed as floating point values, the system has to send them to the embedded system. The connection to the microcontroller board is a standard serial connection following the RS232 norm. The software sent the data on of the communication port of the computer at the rate of 115200 bauds with a standard packet shape of 1 start bit, 8 data bits and 1 stop bit.
Since the microcontroller has an 8-bit architecture which lower drastically the computation power with 32-bits floating point's value, each actuator value is converted into an 8-bit value from 0 to 255. The data sent to the microcontroller are sent as a custom PWM stack in order to reduce the data treatment onboard.
The main objective has been to improve the refresh rate of the HMW.

4.4 Head Mounted Wind

The HMW is mainly composed by a microcontroller board driving 8 personal computer's fan mounted onto a light and rigid structure around the user head as shown in Figure 4.

Figure 4 : Head Mounted Wind system

The main component is the microcontroller board, shown in Figure 5, in charge of collecting the data from the serial port of the computer, keeping track of the state of system by generating error messages, and emulating the 8 Pulse Wide Modulation (PWM) outputs to drive the fans.

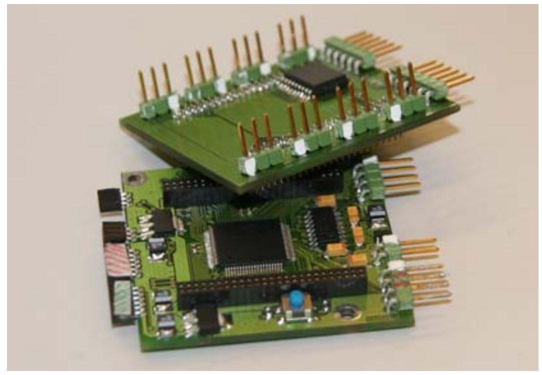

Figure 5: microcontroller board

The board has been designed around the micro-controller PIC18f8722 manufactured by the Microchip Company. This micro-controller has an 8-bit architecture and is synchronized by an external quartz oscillator running at 40MHz. It includes an USART module for serial communication linked to a voltage converter to match the RS232 standard. The actuators are driven by eight numeric switches which convert the 5V command signals from simple digital output of the microcontroller into a 12V power signal to the fan actuators.

The limitation of the number of micro-controller's hardware driven PWM outputs to 5, induces the needs of emulation in order to drive the 8 actuators of the HMW system through normal digital output. The emulation of the PWM output is based on an internal backward counter which can be set and generates an interrupt on reset. The method used to emulate different outputs out of a single timer is to computes the different time steps taking each change of the outputs as a whole entity. The software sets the counter to this time steps and updates the values of the outputs with the desired values when the time step is over. In order to provide error proof communication, a minimal protocol packet has been used between the computer and the microcontroller providing a header, length and ending byte codes. Each time the system receive valid PWM information, it store it during the completion of the active PWM period. At the following period the received stack is used to generate the desired outputs. Once the stack has been parsed once, an acknowledgement message is sent to the computer which will send new values. The overall refresh rate is around 50 Hz.

The actuators of the HMW are standard 12V PC tower Fan as shown in Figure 6. The fan core is a 12V DC motor. The motor is running faster as the supplied electrical energy increases. Receiving a fast PWM input compared to the electrical inertia of the motor consists in coding the percentage of power to pass to the electrical engine. Their maximal speed is around 2000 rpm. They are also very low noise emitter.

Figure 6: Fan actuator

The actuators are mounted on a balsa wood structure attached with strings to a classical Head Mounted Display. The added weight of the device to the HMD is fairly low, around the kilogram. Following the system description, the next part will present the tests and results on its use on this particular application.

5. Tests and results

For validation purpose, we made a set of persons test the flight simulator enhanced with our Head Mounted Wind system as shown in Figure 7. Five different users, three men and two women from 20 to 35 years old all beginner with piloting aircrafts, pass a 20 min experiment. In the first time we let the user familiarize with the control of a glider within the flight simulator. After a small training period we activate the Head Mounted Wind system.


Figure 7: Test Bench

The main objective for the user is to sustain his aircraft as long as possible by facing the wind in order to generate the maximum relative speed. We make the user turn in circle for disorientation purposes and check is response time to find the wind direction. Since we changed randomly the wind direction between attempts, the user only relies on the head mounted wind system. In order to mask the sound of the fan, which can help in determining from where the wind is coming from, loud speaker are used to pass the sounds from the flight simulator.
By collecting the user overall feeling, we had mostly positive feedback in the ability of the device to improve immersion in the simulation. The users find this device very natural to use and greatly improve the sense of presence. Although this feedback is mainly subjective to the users feeling it shows undeniably that it serves this purpose.

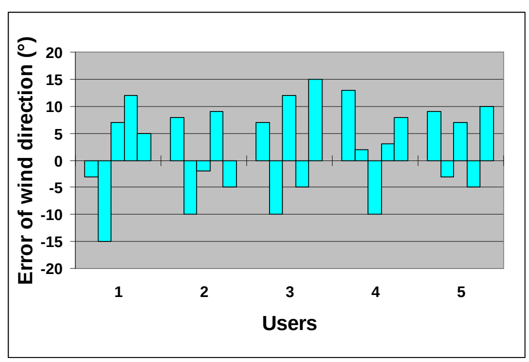

Figure 8: Error of estimation of wind direction

The results of the wind direction, see Figure 8, shows interesting results since the average error in finding the wind direction has a standard deviation of 8.5° among the different users. This result is encouraging and definitely shows the usability to provide wind direction information to the user. The results vary also from one attempt to another. A possible limitation of those tests is coming from the ability to pilot the airplane in the simulator.
We notice that it is difficult for people wearing rather long haircut to sense the wind in the back since it is blocked by the hairs. One of the main issues to deal is the latency of the system due to the inertia of the fan and the relatively slow speed of the wind. Those issues should be attempted in further development in order to establish a precise validation procedure using a larger test population and comparison to others cues as visual, audio and or vibrotactile.

Conclusion and further work

This device presents interests in its use to improve immersion inside virtual environment and tele-presence. It provides good orientation feedback and can be used to pass extra information to the user. The lack of researches in this field makes this device innovative and will offer new field of applications.

Still further works on improving the current system are planned. The first issue will be to increase the strength of the produced wind by increasing the fan speed or their size. We will also work on the wearability of the system by adding wireless connection interface and driving it from a handheld device. The size and the weight of the whole system have also to be drastically reduced. The main reason for improving its wearability is to use this system for tele-operation application with light weight aircraft.

Further application could be also created for improving immersion in virtual environment. Relevant application can be found also were the wind plays an important role such as in a golf course simulation.

Acknowledgements

This work has been partially founded and supported by the european network of excellence Intuition.

References

[1] Heilig, M. (1955). El Cine del Futuro (The Cinema of the Future), Espacios: Mexico City. Reprinted in Presence 1(3), 1992.
[2] Pflimlin, J.M.; Soueres, P.; Hamel, T., Hovering flight stabilization in wind gusts for ducted fan UAV, Decision and Control, 2004. CDC. 43rd IEEE Conference on, Vol.4, Iss., 14-17 Dec. 2004, Pages: 3491- 3496 Vol.4
[3] Quigley, M.; Goodrich, M.A.; Griffiths, S.; Eldredge, A.; Beard, R.W., Target Acquisition, Localization, and Surveillance Using a Fixed-Wing Mini-UAV and Gimbaled Camera, Robotics and Automation, 2005. ICRA 2005. Proceedings of the 2005 IEEE International Conference on, Vol., Iss., 18-22 April 2005, Pages: 2600- 2605.
[4] Righetti X., Cardin S., Thalmann D., Vexo F. Immersive flight for surveillance application, IEEE symposium on 3D Interfaces 2007, 10-11 March, Charlotte, North Carolina, USA, 139-142
[5] Heeter, C. 1992. Being there: the subjective experience of presence. Presence: Teleoper. Virtual Environ. 1, 2 (May. 1992), 262-271.
[6] Bryson, S. and Levit, C. 1992. The Virtual Wind Tunnel. IEEE Comput. Graph. Appl. 12, 4 (Jul. 1992), 25-34
[7] Deligiannidis, L.; Jacob, R.J.K, The VR Scooter: Wind and Tactile Feedback Improve User Performance. 3D User Interfaces, 2006. 3DUI 2006. IEEE Symposium on, Vol., Iss., 25-29 March 2006 Pages: 143- 150
[8] Dionisio, J., Virtual hell: a trip through the flames, Computer Graphics and Applications, IEEE, Vol.17, Iss.3, May/Jun 1997 Pages: 11-14
[9] http://www.ambx.com (accessed march 2007)