Haptic Weather

Chaehyun Lee[1,2] Bernard D. Adelstein[2] Seungmoon Choi[1]

[1] Haptics and Virtual Reality Laboratory
Department of Computer Science and Engineering
POSTECH, Republic of Korea

[2] Human Systems Integration Division
NASA Ames Research Center
Moffett Field, CA, USA

ABSTRACT

We overview a new approach for displaying meteorological information in which weather features extracted from weather maps are rendered haptically. This weather display enables users to feel the weather at the geographic locality indicated by the position of the interface cursor. At present, we are exploring haptic metaphors representing wind, precipitation, and turbulence, factors relevant to aircraft flight trajectory planning.

KEYWORDS: Haptic Interaction, Weather Display, Air Traffic Management

INDEX TERMS: H.1.2 User/Machine Systems: Human Factors; H.5.2 User Interfaces: Haptic I/O

1 INTRODUCTION

US air traffic volume is expected to more than double by the year 2025. The Next Generation Air Traffic System for the US as currently envisioned will accommodate this growth in traffic through the redistribution of air traffic management functions from the current ground-based control architecture to a more extensive network in which enhanced computational, planning, and monitoring functions will also be shared with aircraft. [1] Fundamental to Next Generation concepts is the deployment of planning tools that incorporate not only trajectory information from multiple aircraft, but also enhanced weather models. [1]

Though some foresee a fully-automated air traffic system assuming responsibility for monitoring and control of the national airspace, as in many other highly specialized technical areas (e.g., medicine), human information integration and decision-making capabilities will likely continue to be offer advantages. Human supervision and intervention on the flight deck, however, necessitates the availability of high-quality information displays and interaction tools.

Colleagues at the Ames Research Center have demonstrated Cockpit Situation Display (CSD) technologies that enable crews en route to interactively input and visually evaluate alternate flight trajectories. [2] Their underlying CSD software provides real-time graphical feedback of constraint violations such as insufficient separation from other aircraft, terrain and, more recently, weather. Interaction with the CSD, however, depends on visual observation that can episodically deflect user attention from other resources such as the primary flight display or out-of-the-window views.

We are beginning to explore the possibility of augmenting CSD interaction through the addition of haptic feedback of flight and environment data to the user. Our longer-range objective is to determine whether and how to distribute information across multiple sensory channels to enhance operational efficiency and lessen workload on the flight deck. In this sketch, we overview our initial exploration of techniques to haptically render weather on a regional or national scale for potential inclusion as an element of an interactive flight planning tool. Specifically, we examine weather attributes that contribute to air traffic scheduling and safety.

2 WEATHER INFORMATION

Real-time weather information is available in a variety of formats including tabulated digital data, graphical representations, or even audio descriptions. In this work, we employ graphically represented weather maps as data sources for several reasons. First, it is easy to directly process information from map images, in which color and other graphical symbols indicate geographically distributed phenomena. Second, by using graphical weather products, we capitalize on existing pre-processing tools that convert digital streams of local weather data into a nationwide, geographically-based representation. Finally, detailed national-scale weather images are freely accessible via a number of commercial and government internet sites.

3 HAPTIC REPRESENTATION

We employ a selection of images from Weather Underground (http://www.wunderground.com), a commercial website that delivers current meteorological information for the entire US. Specifically, we work with types of information pertinent to flight planning: wind, turbulence, and precipitation. Other available images such as temperature or humidity maps are less important to en route application, and are also not transformable into transparent (i.e., obvious) force-feedback sensations. The haptic effects we have chosen are being designed to literally and, therefore, we hope, intuitively represent the weather conditions being displayed. Our ultimate goal is to concurrently and unambiguously provide the user with geographically collocated wind, precipitation, and turbulence information.

3.1 Wind

Surface wind direction and speed are represented as vector arrows in the map image shown in Figure 1. (Similar wind map images are also available for other elevations.). The start point of each arrow is located on an equally spaced grid while the arrows themselves have a specific, unique color. Using these attributes, wind vectors can be easily quantified at the grid points in the image. Based on the wind vectors, we can calculate a reactive force direction tangential to the map surface representing wind direction as well as a force magnitude linearly proportional to wind speed.

In order to convey continuous and smooth wind speed between grid points, we use force shading and temporal interpolation. The force vector at the cursor is determined by the weighted spatial combination of wind force vectors at the three vertices of the currently occupied triangular patch [3], as illustrated in Figure 2. To minimize the perception of discontinuity, specifically when

xlos@postech.ac.kr
Bernard.D.Adelstein@nasa.gov
choism@postech.ac.kr

Symposium on Haptic Interfaces for Virtual
Environments and Teleoperator Systems 2008
13-14 March, Reno, Nevada, USA
978-1-4244-1972-2/08/$25.00 ©2008 IEEE

crossing between triangle patches, the force vector is interpolated according to a third-order polynomial time function. Due to this interpolation operation, the force output is delayed with respect to cursor position by 100 ms. The effects of the delay, however, are not apparent to the user.

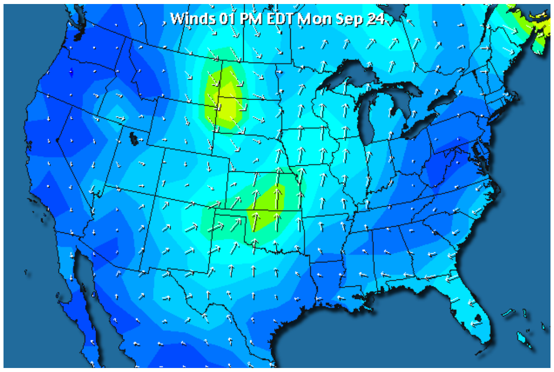
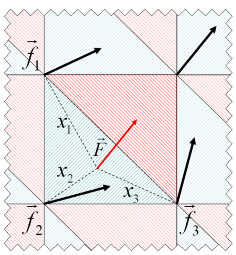


Figure 1. US surface wind map from www.wunderground.com



$$\vec{F} = \frac{\sum_{i=1}^{3} x_i (\sum_{j=1}^{3} \vec{f}_j - \vec{f}_i)}{\sum_{i=1}^{3} x_i}$$

Figure 2. Force Shading

3.2 Turbulence

Our most common encounter with atmospheric turbulence is the bumpy sensation experienced on an airplane flight. Input data for the turbulence display is derived from color zones on an aviation turbulence potential map. We render turbulence using a Perlin Noise model [4] to force pseudorandom vibration in the height direction, as shown in Figure 3.

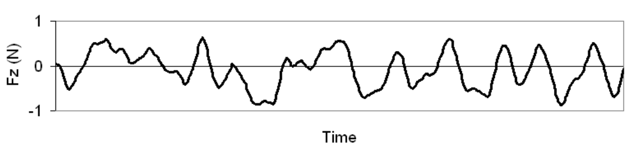


Figure 3. Force profile applied when turbulence occurs

3.3 Precipitation

To haptically represent precipitation magnitude, the tooltip of the haptic device is treated as an umbrella on a rainy day. The force is applied in the height direction (perpendicular to the map) with a sine function profile giving the user the "feeling" of individual raindrops. When the user's cursor is over a light precipitation area, the raindrop pattern felt is sparse and weak. In contrast, when the cursor is on a heavy precipitation area, the user feels a dense, strong pattern. Presently, we convert precipitation information from color zones on maps representing the previous 24-hour accumulation. (Alternatively, current precipitation intensity can be extracted from available Doppler radar based images.) As shown in Figure 4, stimulus frequency (1/period), duty cycle (1.0 minus the proportion of time for zero force between raindrops) and amplitude are adjusted to imitate the natural phenomenon.

Precipitation (in)	Symbolic color	Period (ms)	Duty cycle	Amplitude (N)	Force Profile
0.1 ~ 0.5		525	0.24	1	
0.5 ~ 1.0		466	0.36	1	
1.0 ~ 1.5		400	0.63	1	
1.5 ~ 2.0		320	0.78	1	
2.0 ~ 3.0		270	0.93	1	
3.0 ~ 4.0		166	1.00	1	
4.0 ~ 6.0		125	1.00	1	
6.0 ~ 8.0		100	1.00	1.3	
8.0 ~ 10.0		100	1.00	1.7	

Figure 4. Parameters and force profiles for precipitation

4 Discussion

We demonstrated a method to extract weather information according to the location of a hand-driven cursor on a set of weather maps, compute and sum the force profiles representing the data from each map, and display the summed forces to the user via off-the-shelf hardware such as SensAble's Phantom Omni and Novint's Falcon. Like any other stylus-based haptic application, our weather display provides information only at the instantaneous cursor location, which may not help the user comprehend the global weather situation. However, the display can potentially deliver concurrent feedback for a combination of collocated local weather attributes that may otherwise be difficult to appreciate when presented visually, whether on a single overlaid map or on multiple adjacent ones. Although the differences between the three types of haptic weather stimuli discussed are readily discernable when rendered separately, the appropriate perceptual range and resolution of stimulus magnitudes for the individual weather effects (cf., [5]), both alone and in combination, will first need to be studied. Finally, the utility of integrating such haptic concepts into visual CSD applications also needs to be investigated.

Acknowledgment

This work was supported by the NASA Airspace Systems Program's NGATS ATM-Airspace Project and the Korea Research Foundation.

References

[1] Arbuckle, D., Rhodes, D., Andrews, M., Hallowell, S. Baker, D., Burleson, C. Howell, J., & Anderegg, A. (2006) U.S. Vision for 2025 air transportation, *ATCA Journal of Air Traffic Control*, *48*(11): 15-21.

[2] Granada, S., Dao, A. Q., Wong, D., Johnson, W. W., & Battiste, V. (2005). Development and integration of a human-centered volumetric cockpit display for distributed air-ground operations. *Proc. 12th International Symposium on Aviation Psychology*, Oklahoma City.

[3] Morgenbesser, H.B., & Srinivasan, M.A. (1996) Force Shading for Haptic Perception, *Proc. ASME Dynamic Systems and Control Division*, vol. 58, pp. 407-412.

[4] Perlin, K. (1985) An image synthesizer. *Computer Graphics*, *19*:287-296.

[5] Omata, M., Ishihara, M., Kwok, M.G., & Imamiya, A. (2005) Hapticizing wind on a weather map with reactive force and vibration, in M.F. Costabile and F. Paterno (Eds.), *INTERACT*, pp. 18-29.