Odor Playback Based on Computational Fluid Dynamics Simulation

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Abstract

The results of our current research efforts on the development of an olfactory display system are demonstrated. To provide realistic smells with appropriate intensities in a virtual reality system, we propose to use computational fluid dynamics (CFD) simulations in conjunction with the olfactory display system. A CFD solver is employed to calculate the turbulent airflow field in the given environment and the dispersal of odor molecules from their source. An odor blender is used to generate the odor with the concentration determined based on the calculated odor distribution. Two types of demonstrations are provided: presenting odor stimuli synchronously with a movie clip and generating odor stimuli together with a changing airflow field.

1. Introduction

An olfactory display is a device that delivers smells to the user's nose. It can be used to add "special effects" to a movie by releasing smells relevant to specific scenes shown on the screen (Fig. 1). It also helps in attaining a higher level of presence in a virtual reality system. In order to achieve successful presentation of smells, however, some technical issues need to be solved. Most of the research work so far is addressed to the development of the hardware for generation and delivery of smells. How to adjust the strength of a smell is also a problem. The appropriate release rate of an odorant for a faint scent drifting in air and that for a malodor hitting the nose can be extremely different.

Our current research efforts are aimed at establishing a method for automatic adjustment of the release rate of smells. Diffusion of odor molecules into air is an extremely slow process (a few tens of centimeters per hour). In most indoor and outdoor environments, the airflow velocity dominates the slow diffusion rate. Odor molecules released from their source are carried by airflow and from an aerial trail in the downwind direction. Therefore, we propose to use computational fluid dynamics (CFD) simulation to calculate the airflow filed in a given environment and the resultant odor distribution. The concentration of the odor at an arbitrary coordinate and time instance can be obtained from the simulated data. The concentration value is passed to an odor blender to adjust the release rate of an odorant, and thus, the variation in odor intensity that the user would experience in a real-life situation is reproduced. Two types of demonstrations are provided here to show the odor playback based on CFD simulations. Further information can be found in [1].

2. Presenting odor with a movie clip

A movie clip shown in Fig. 2 was prepared using OpenGL for the first demonstration. Three teapots are placed on the floor in the three-dimensional model of a room (5.8 m × 3.2 m × 2.7 m). One of the teapots is assumed to be full of peach tea. The viewpoint of the movie clip is moved assuming a small animal, e.g., a rabbit, slowly walking through the room. The user is asked which teapot is containing the peach tea after experiencing the change in the smell with the movement of the viewpoint. A stop for 10 s is made in front of each teapot so that the user can check its smell. The vertical screen shown in the captured images is placed to add some complexity to this simple scenario. It acts as an obstacle for the airflow field and the odor distribution.

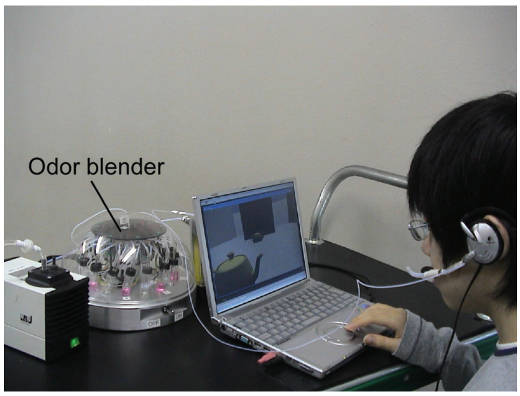

Figure 1: Odor playback with a movie clip.

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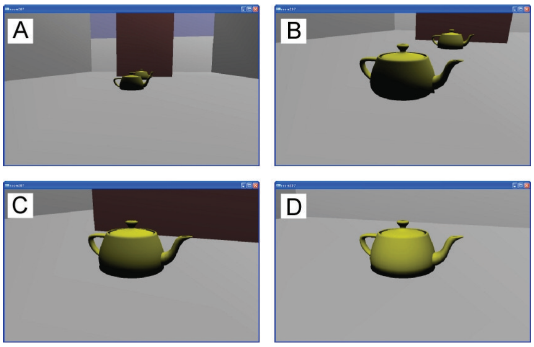

Figure 2: Snapshots captured from the movie clip. (A) Starting position. (B)–(D) Stops made in front of teapots.

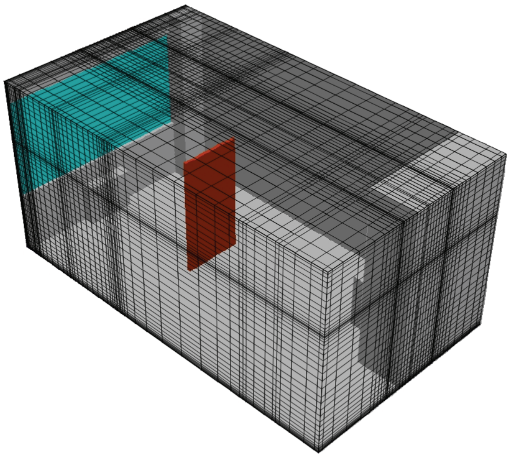
Figure 3: Computational grid used for CFD simulation.


Figure 4: Electric fan and teacup.

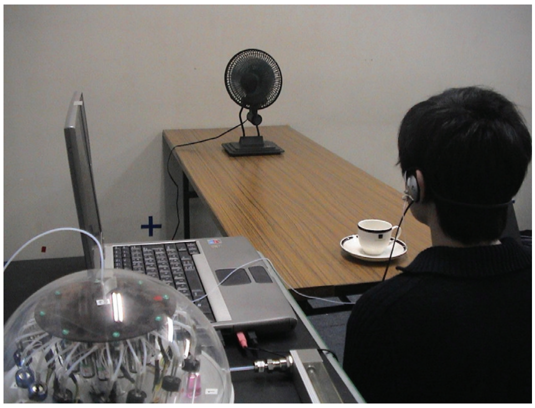
Figure 5: Odor playback with a changing airflow field.

The computational grid shown in Fig. 3 was generated by dividing the OpenGL room model into 63 × 43 × 46 cells. The airflow in an environment of a scale relevant to our daily lives is almost always turbulent. Therefore, the standard k-ε turbulence model was used in the calculations. Firstly, natural convection created by the temperature variation in the room was calculated. The transport of odor molecules was then simulated to obtain the distribution of the odor concentration.

While the movie is shown on a computer monitor, the smell of peach tea is generated using the odor blender shown in Fig. 1. The blender has computer controlled solenoid valves to adjust the concentration of the generated smell by mixing the odor vapor with clean air. The technical details of the odor blender can be found in [2]. The tube for the odor delivery is attached to the headset so that the position of its tip is fixed near the nose of the user.

3. Generating odor with changing airflow

The scenario assumed in the second demonstration is shown in Fig. 4. An electric stand fan is set behind a teacup filled with peach tea. When the fan is turned on, it starts to oscillate. If you sit in front of the teacup, the vapor evaporated from the peach tea is carried to your nose by the airflow generated by the fan. Therefore, you would perceive the smell of the peach tea periodically.

In the demonstration, the user is asked to sit in front of a real electric fan and an empty teacup at the specified distance (Fig. 5). CFD simulations were conducted to obtain the data on the odor distribution and its change with time. The odor is delivered to the user's nose using the odor blender while the fan provides the real oscillating airflow. If the assumed scenario is successfully reproduced in the simulations, you will feel the smell of the peach tea at the time you feel the puffs of airflow from the fan.

References

[1] H. Ishida, H. Matsukura, H. Yoshida, and T. Nakamoto. Application of computational fluid dynamics simulation to olfactory display. Poster presentation at ICAT 2008.

[2] T. Nakamoto and H. P. D. Minh. Improvement of olfactory display using solenoid valves. Proc. IEEE Virtual Reality Conference: 179–186, 2007.