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Understanding the effect of background awareness in urban wind environment visualizations to minimize information entropy

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ABSTRACT

Visualization is a powerful technique for showing invisible physical phenomena. However, simulation administrators must identify accurate methods of presenting information to non-experts via visualizations. The color scheme of the simulation area and the coverage of contour colors throughout the visualization have significant impacts on the viewers' ability to understand the graphic. In this study, experiments were performed to assess the urban wind environment of new building construction projects that cause strong winds. Two different pictures with and without countermeasures against strong winds were compared by the participants in the experiment. Although the participants understood that improvements were made to the wind environment when a conventional contour scheme was used, a statistically significant decrease in the probability of correctly understanding the visualization was observed when the contour color scheme was reversed. The participants' ability to understand the visualization was disrupted when the graphics were mostly red. The participants related the color of the image to the sensation of a windy environment based on their background awareness. The results suggest that the simulation administrator should be careful when presenting information and should consider the comprehensive image perceived by the viewer based on their personal background awareness.

1. Introduction

Computational technologies are widely utilized in the architectural industry, and the development of these technologies has led to increased use of computer visualizations in actual practice to virtually show physical models (Bouchlaghem, Shang, Whyte, & Ganah, 2005). The development of simulation technologies allows one to visualize invisible physical information, such as airflow, thermal properties and sound intensity, as well as phenomena in human bodies via computer-generated graphics (Asawa, Hoyano, & Nakaohkubo, 2008; Ito et al., 2016; Karol Karch, Sadlo, Weiskopf, Munz, & Ertl, 2012; Lim, Imran, & Yong Jeon, 2016). These visualizations help people understand the invisible internal and external physical statuses of buildings.

For instance, computational fluid dynamics (CFD) is a powerful technique for understanding airflow and heat and mass transfer caused by airflow. Researchers have utilized CFD analyses to accumulate considerable knowledge of building environmental science (Blocken, 2015; Wang & Zhai, 2016). In the past, the simulation techniques used for large computational resources have represented a barrier to applying these techniques to architecture and urban planning. In other words, simulation technologies have mainly been used for research. The recent dramatic development of information technologies has expanded the application of these techniques to other disciplines. Some attempts, e.g., a training program for CFD applications (Tsou, 2001), have been contributing to increasing the number of people able to use these tools to solve design problems. Moreover, the development of simple interfaces has made such tools more user-friendly and increased the number of users (Broderick & Chen, 2000). Against this background, visualization tools have been developed to extract information that is meaningful to the end user (Ozell, Camarero, Garon, & Guibault, 1995). Communication tools have also been developed to provide visualizations for persons without expertise (Ono & Morikawa, 2001; Sato, Hoyano, & Asawa, 2011), and tools that apply simulation outputs to virtual reality have also been developed (Fukuda, Mori, & Imaizumi, 2015). The development of building information modeling (BIM) helps architects utilize simulations in their decision making as the building design progresses (Sumi & Doosam, 2010). However, whether users can accurately understand the information presented in visualizations has not been fully discussed. When a simulation administrator and the receiver of visualized information are the same, e.g., a researcher using a

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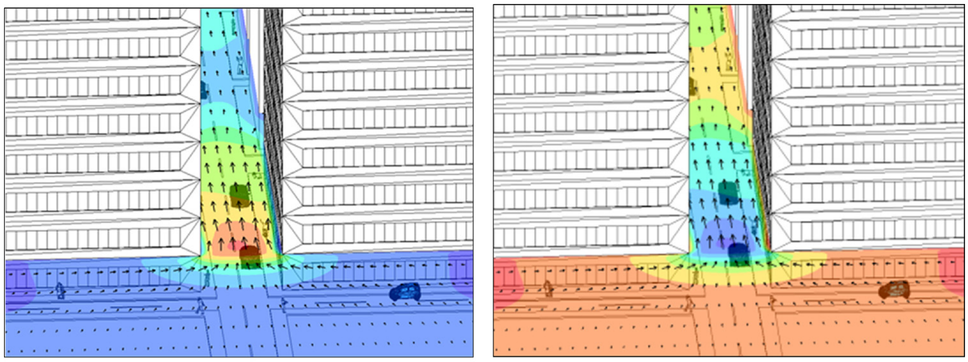

a) conventional contour color scheme   b) reversed contour color scheme

Fig. 1. Wind environment visualization.

simulation to understand physical phenomena, then it might be possible for the administrator to generate an adequate simulation output to analyze what he/she wants to know. However, when the simulation administrator and the receiver of the simulation output are different, then there is no guarantee that the administrator will provide adequate information to the receiver. For instance, in urban planning, CFD analyses are frequently used to show the wind environment in planned urban regions to civilians (Shi, Zhu, Duan, Shao, & Wang, 2015). Basically, an annual based urban wind assessment should be performed to show the probability of exceeding tolerable wind levels (Melbourne, 1978; Murakami, Iwasa, & Morikawa, 1983), especially when city planners must use data to convince the public of their city development ideas. However, wind assessments using fixed boundaries are still used to investigate urban wind environments (Adamek, Vasan, Elshaer, English, & Bitsuamlak, 2017; Fintikakis et al., 2011), especially the wind distribution across the relevant fields. If the wind is visualized with relatively long vectors and colored vividly, then the visualization might project an image of strong wind regardless of whether the actual wind speed is strong. A table relating the visual color scheme and wind speed is usually attached to the visualization. However, people without expertise may find it difficult to understand wind environments based on the numerical value of the wind speed. Visualized information itself becomes essential information for civilians to determine whether the wind environment is acceptable, although miscommunications among viewers may occur. Ideally, the simulation would be performed by someone with adequate expertise, and the results would be shown to viewers with an adequate expert interpretation. However, the recent dramatic development of information technology and user-friendly CFD software has accelerated the trend toward use by non-expert administrators to produce pictures to convince the viewers of their ideas. In this context, miscommunication should be avoided by investigating how non-experts receive information through CFD visualization. This study is necessary to prevent user-friendly CFD software from being used merely as a drawing tool rather than an analysis tool. A similar problem could arise when analyzing thermal environments are analyzed, a task that is often performed using CFD analysis (Dimoudi et al., 2014). The proper use of a color scheme is an important factor when presenting images of thermal statuses. Visualizations using warm colors, such as red and orange, can generate the impression of a warm environment.

To avoid these miscommunications, research analyzing how people perceive information from visualizations is essential. Ishii et al. (Ishii et al., 1998) observed that although "a particular source of information may occupy the “foreground” of our awareness, many additional sources may concurrently be monitored in the “background” "; accordingly, visualizations should be created after carefully considering how they impact viewers' background awareness. Through an accumulation of such studies, the receivable information in visualizations could be universalized, which would minimize the information entropy in visualizations.

Authors have focused on this topic, especially in the visualization of urban wind environments. Conventionally, the color red is used for high values and the color blue is used for low values in contour color schemes of visualizations. Following this convention, high-speed and low-speed winds would be colored red and blue, respectively. This color scheme is naturally acceptable for experts and researchers. However, the color blue generally corresponds to cool temperatures. Because wind can have a cool effect on human thermal sensation, people without expertise might correlate blue color with strong winds. In this context, relatively strong winds should be colored blue. The wind environment and the temperature distribution tend to be analyzed at the same time. When an urban environment is analyzed, the above city area is, in addition to being colored red due to the high wind speed on the wind environment map, colored blue in the temperature map due to its low temperature (Tominaga, 2012). In these cases, it may be meaningful to reverse the color scheme used for the wind speed. Methods of coloring wind in visualizations should be discussed according to the individuals who will be receiving the visualizations. In a previous study (Okada, Hiyama, Matsuda, & Koganei, 2016), the authors investigated the information imparted by color in visualizations of wind environments, and we found that the color coverage ratio in the visualization had a significant impact on how people intuitively understood the displayed wind environments. Based on the research results, the authors conducted new experiments to discuss the color scheme for wind environment visualizations in cases where new building construction may cause a strong wind to blow through tall buildings. In this paper, a review of previous research is presented first, and then the results from new experiments are described.

2. Impact of color scheme on the visualizations of wind environments

In a previous study, the impact of color on the visualization of wind environments was investigated [Note1]. In addition, an experiment was conducted to investigate which contour color scheme is appropriate for illustrating a strong wind blowing through two tall buildings. Fig. 1a) (Okada et al., 2016) presents a wind environment visualization with a conventional color scheme used by researchers. Red and blue colors are used for high-speed and low-speed winds, respectively. Fig. 1 b) (Okada et al., 2016) is a wind environment visualization with the reversed contour color scheme considering the emotional perception of wind by the public.

Blue is used for strong wind because the color blue corresponds to cool temperatures and wind has an effect of human thermal sensation; thus, the color scheme seems to be more acceptable to the public. The