Visual conflicts - Challenges in combining rich volumetric 3D-data in a realistic VR city model

Beata Stahre Wästberg[1], Fabio Latino[2,1], Thommy Eriksson[1], Daniel Sjölie[3], Orfeas Eleftheriou[2], Vasilis Naserentin[2] and Håkan Pleijel[4]

B. Stahre Wästberg (Corresponding author) • T. Eriksson
Department of Computer Science & Engineering, Chalmers University of Technology, 412 96 Gothenburg, Sweden
Email: beata.wastberg@chalmers.se

T. Eriksson
Email: thommy@chalmers.se

F. Latino • O. Eleftheriou • V. Naserentin
Digital Twin Cities Centre, Chalmers University of Technology, 412 58 Gothenburg, Sweden
Email: latino@chalmers.se

O. Eleftheriou
Email: orfeas@chalmers.se

V. Naserentin
Email: vasilis.naserentin@chalmers.se

D. Sjölie, School of Business, Economics and IT, Division of Informatics, University West, 461 86 Trollhättan, Sweden
Email: daniel.sjolie@hv.se

H. Pleijel, Department of Biological & Environmental Sciences, University of Gothenburg, Botanhuset, Box 461, 405 30 Gothenburg, Sweden
Email: hakan.pleijel@bioenv.gu.se

1. Introduction

A goal for future cities is to create urban environments that are dense, yet green and sustainable regarding health and wellbeing. It is crucial to understand how vegetation, denser building structures and future traffic situations affect air quality. By visualizing invisible environmental data in a city model, an improved understanding of environmental impacts can be achieved. This paper presents a work in progress on how to visualize the impact of vegetation on urban air quality in a virtual city model, explorable using virtual reality (VR). The transdisciplinary project *CityAirSim - Visualizing and modelling urban air quality - influence of vegetation, building morphology and traffic emissions*[1] develops a modelling framework to simulate the effects of vegetation, buildings and traffic strategies on air pollution, in order to understand the synergies and conflicts between these factors. The resulting data will be visualized in a VR-application allowing interactive exploration. Two primary target groups for the VR-application are high school students and urban planners. We aim for the tool to be used in teaching, e.g., in environmental science, as well as in communication with the public in exhibition environments, such as science centers.

This paper focuses on how we should visualize invisible air pollution in an otherwise realistic urban setting to facilitate understanding. One important aspect to consider is to create a visual balance between data visualization and the visualization of the built environment in the model. Another aspect is to define the appropriate levels of data visualization and abstraction of representation to use, without losing richness of information.

By visualizing environmental data in city models, an improved understanding of environmental impacts can be communicated (Stahre Wästberg et al 2017). Such models are usually presented in a bird's eye view. For the pedestrian's experience of the environment, a street view perspective could be more suitable. Representation of data is a challenge for implementing visualization as a communication tool in urban planning (Billger et al. 2017). To facilitate understanding and to see relations between different results, cause and effect scenarios are of interest, as well as to show more than one parameter simultaneously (Jamei et al 2017, Batty & Hudson-Smith, 2014). In recent studies methods have been developed for representing environmental data in city models, i.e. to define appropriate visual styles and levels of realism and detail (Stahre et al 2020, Bartosh & Gu, 2019, Stahre et al 2017, Ketzler et al., 2020, Jamei et al 2017).

---

[1] https://www.mistraurbanfutures.org/en/node/2925

2. Methodology

We have used design-based research (Anderson & Shattucki, 2012), which is an iterative method where design concepts have been tested and evaluated in workshops with end-users, as well as internal evaluations with the research team. Several scenarios were designed and developed as 3D-environments corresponding to a baseline version (current city area) in central Gothenburg, Sweden, as well as potential future developments. The game engine Unreal Engine (version 4.26) was used, enabling real-time exploration and natural interaction using, e.g., VR. The scenarios were designed to allow the user to explore the impact of different building and vegetation configurations on air flow and circulation, and the resulting air quality. VR has two important advantages here, 1) natural and interactive exploration enables the user to easily move around and explore the data from multiple perspectives, building an understanding of data in 3D-related to everyday interactions with real (3D) space, and 2) presenting data in a naturalistic context helps the user connect the presented information to potential impacts in their real environment, making it more memorable and more potent in influencing future actions and decisions.

Different methods for visualizing air pollution (particles and NO_2) were developed and tested in the model, including cut planes and glyphs (coloured points/spheres) covering a grid (Image 1a, b). Attributes such as colour, transparency, shape, density, and movement of glyphs were investigated.

Due to the covid-19 pandemic, all workshops demonstrating the VR-applications have been done remotely, via video meetings using Zoom. To give as much understanding of the VR-application as possible under the circumstances, one of the researchers ran the application in VR and streamed the screen view to Zoom. Workshop participants could direct the researcher, asking for different views and interactions to be performed. The demonstrated VR-application is a working prototype; it includes the final city configuration, and semi-finalized versions of the visualization and the interaction. Three workshops have been held during 2020, of approximately one hour each, involving a total of 20 different participants representing city planners, teachers, and similar stakeholders. On-site user tests with planners and students are planned for the autumn 2021.

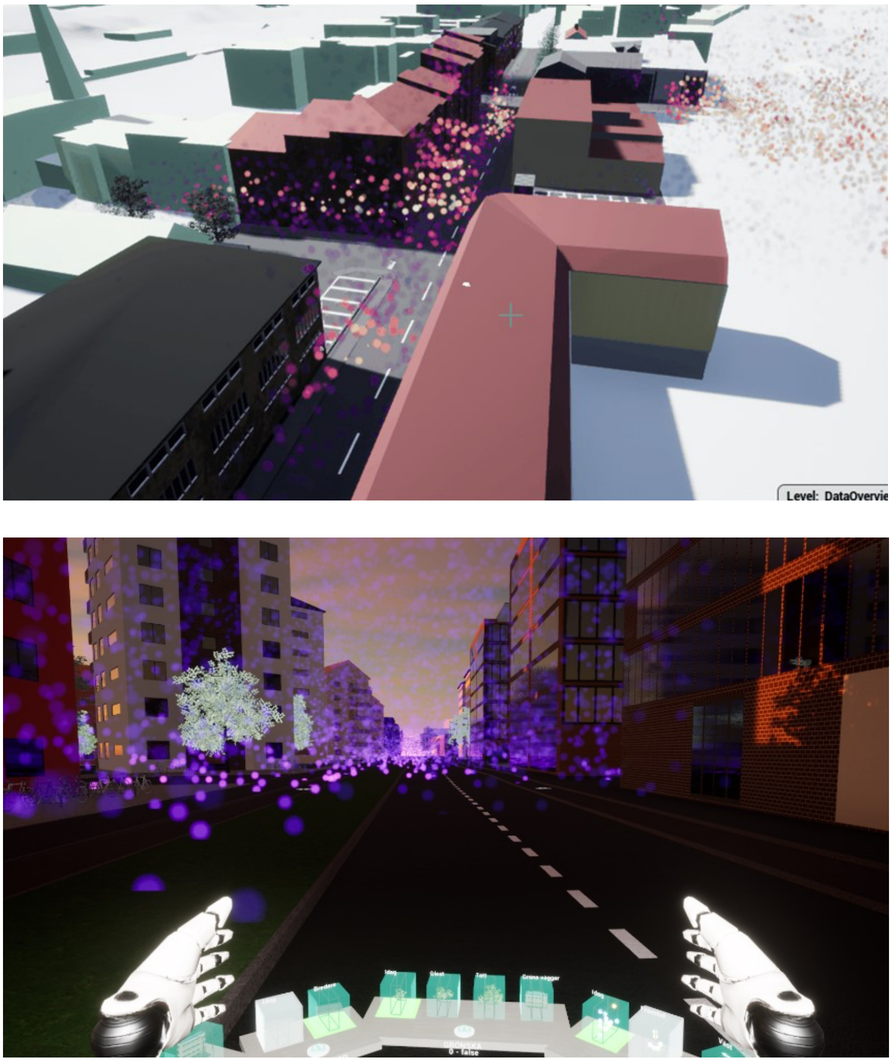

Image 1a, b. Example of glyph visualization of particles from bird's eye view and street view (showing different scenarios).

3. Results and Discussion

Virtual reality provides many ways of displaying and communicating data in ways that are engaging and different from traditional 2D-visualizations. These conditions for displaying data also come with a new set of challenges concerning representation.

When visualizing environmental data in a 3D-model, one must consider how the surrounding setting affects the appearance of the invisible parameters, and impact, e.g., how colours are perceived. This concerns, e.g., level of lightness, colour intensity and detailing. Results from workshops and evaluations within the research team have shown the importance of being very clear when visualizing information in 3D. One thing that was repeatedly noted in workshops was a desire to have simpler visualizations of the air pollutants, focusing on key thresholds and a small number of steps in the colour scales used for visualizing different values. To clarify different pollutant values, different size and density of glyphs could instead be added as complement to the colour scales. It was also called for to highlight values of interest, such as particularly high, or low, pollution levels. Results showed that more detailed information about air pollution should be optional and accessible by an active choice of the user. When communicating detailed information such as numbers and text it can therefore be better to use a different level of information which can be reached by the user on demand.

Results also showed the importance of using visual contrast between pollutants and the built surroundings to visually discern the invisible parameters from being a part of the physical setting. Enhancing the visual contrast between invisible parameters and the surroundings can help guide the eye of the user. The use of colours can be an effective means for this, both for visualizing the invisible air pollution but also for the surrounding setting. A darker, lighter, or more monochromatic background can aid the attention to focus on more highlighted pollutants. Important to consider is also how someone with colour deficiency can understand the information.

4. Conclusion

In this paper we have discussed challenges for representing air pollution in a 3D-model in the currently ongoing project CityAirSim. 3D-models can provide users with more detailed information about both visible and invisible aspects of an urban scenario. It is however important to consider how to represent the data. Based on workshop results in the project’s iterative design process, we have discovered that it is cognitively difficult to absorb information when invisible parameters are visualized in a physical setting in a 3D-model. It is therefore important to consider what the visual focus for the user should be on. This can be achieved by using means such as enhancing visual contrast, adding different levels of information, and making use of scale and perspective. But above all, by keeping information simple.

References

Anderson, T & Shattuck, J (2012). Design-Based Research: A Decade of Progress in Education Research? *Educational Researcher*, 41 (1), pp. 16–25.

Bartosh, A., & Gu, R. (2019). Immersive Representation of Urban Data. In *SimAUD Conference Proceedings.*

Batty, M., & Hudson-Smith, A. (2014). Visual analytics for urban design. *Urban Design*, 132, 38-41.

Billger, M, Thuvander, L, and Stahre Wästberg, B (2017). In search of visualization challenges: The development and implementation of dialogue tools for supporting urban planning processes. *Environment and Planning B: Planning and Design*, 0(0) 1–24, doi: 10.1177/0265813516657341.

Grainger, S, Mao, F, Buytaert, W (2016). Environmental data visualization for non-scientific contexts: Literature review and design framework. *Environmental Modelling & Software,* 85, 299–318.

Jamei E, Mortimer M, Seyedmahmoudian M, Horan B, Stojcevski A. (2017). Investigating the Role of Virtual Reality in Planning for Sustainable Smart Cities. *Sustainability*. 9(11):2006. https://doi.org/10.3390/su9112006

Ketzler, B, Naserentin, V, Latino, F, Zangelidis, C, Thuvander, L, Logg. A (2020). Digital Twins for Cities: A State of the Art Review. *Built Environment*, 46(4) 547-573.

Stahre Wästberg, B, Billger, M, Adelfio, M (2020). A User-Based Look at Visualization Tools for Environmental Data and Suggestions for Improvement—An Inventory among City Planners in Gothenburg. *Sustainability,* 12(7), 2882; https://doi.org/10.3390/su12072882

Stahre Wästberg, B, Billger, M, Forssén, J, Holmes, M, Jonsson, P, Sjölie, D, Wästberg, D (2017). Visualizing environmental data for pedestrian comfort analysis in urban planning processes. In *Proceedings of the CUPUM 2017—15th International Conference on Computers in Urban Planning and Urban Management*.