Visualization-based Decision Tool for Urban Meteorological Modeling

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Abstract—We present a visualization-based decision tool that enables exploring the link between urban land use and urban weather, in particular predicting and visualizing changes in urban temperature, precipitation, and humidity. Our work combines recent work from urban planning, weather and climate studies, and visualization and computer graphics. Our approach uses an interactive tool to quickly and automatically produce plausible detailed 3D city models by means of a hybrid computational simulation of urban behavior and procedural urban geometry. From the city model, urban morphology parameters are efficiently computed and used by our custom meteorological simulator which considers the influence of the urban landscape. The result is a compelling visualization ability for understanding the complex feedback between urban land use and the regional meteorology of current cities and of potential future cities with desired greening patterns. Our work includes a case study example spanning a 1600 km^2 area.

1 Introduction

In this paper, we provide a visualization-driven decision tool composed of automatic 3D city model generation, urban morphology calculation, and an integrated meteorological simulation. Our work includes a case study example for the city of Indianapolis with prescribed land use change scenarios generated by our tool and the assessment of resulting impact on regional meteorology using a coupled numerical weather prediction model.

1.1 Motivation

Visualizing and assessing the interdependency of dense urban development and local weather is critical to a variety of stakeholders. Urban areas have a high population density and are important seats of socioeconomic activities. Further, as a result of buildings materials and human activities, urban areas are also typically warmer than the surrounding areas. This Urban Heat Island (UHI) phenomenon is well documented (Oke 1988) and has a variety of biophysical, ecological, energy, health, and behavioral impacts (Brunsdon et al. 2009, Eliasson et al. 2007). Urban areas can contribute to the warming of the regional climate (Fall et al. 2009), and thus developing “greener” buildings is being considered as one of the climate change mitigation strategies (Akbari et al. 2009).

Several planning and assessment operations consider urban structures and regional effects but are often performed manually and are time consuming. For example, several works have proposed case-specific landscape and urban planning strategies (Shashua-Bar et al. 2009), ecological concepts (Stremke and Koh 2010), and urban greening methodologies (Bowler et al. 2010, Conway 2009) that improve urban climate and urban life quality.

1.2 Challenges

Our work seeks to enable intuitively exploring “what if” scenarios of the complex feedback occurring between the urban space and the regional weather/ climate. Specifically, we address three challenges which have not been addressed by previous works in a cohesive and coherent framework and consequently have limited the integration of meteorological modeling with urban planning (Eliasson 2000). First, our work builds upon and extends urban modeling and simulation efforts. These systems are typically concerned either with explicit 3D reconstruction of an existing city from photographs or from LIDAR/ laser data, or with simulating the spatial distribution of streets, population, jobs, and other demographic data. The systems are *not* concerned with efficiently creating and changing 3D city models or with modeling the effects on the regional meteorology.

Second, we improve meteorological modeling systems by including urban land surface interactions in the simulation and by automatically computing the necessary urban morphology parameters. While a few meteorological systems support land surface models at high spatial resolution (e.g., 1 to 10 kilometers) and explicitly represent the urban land surface and the associated energy balance (e.g., Masson 2000), in all cases the computation of the urban morphology requires an a priori detailed 3D knowledge of the desired (future) urban space and often manually computes urban morphology parameters. In contrast, we combine our 3D city model exploration tool with automatic calculation of urban morphology values in order to easily calculate meteorological predictions.

Third, while the impact of the urban landscape on regional weather is well documented (Cotton et al. 2003, Niyogi et al. 2006 and 2010, Oke 1988, Shepherd et al. 2002), visualizations have usually been limited to strictly viewing, a posteriori, simulation data using map-based representations and choroplethic renderings of spatially-varying data. They do not exploit the visualization notion that users are comfortable with viewing and understanding 3D models of urban landscape and visualizations of meteorological effects. Even without inspecting up close