Introduction
The complex interaction between various types of urban form and their potential energy use and air quality is poorly understood. The problem addressed by this research is to increase knowledge for how environment and urban form interact through use of high performance environmental simulation using CUDA and related GPU technology. Our hypothesis is that urban structures and layouts exist which can minimize energy use while also minimizing air pollution exposure. Our approach is to develop an extremely fast and inexpensive energy use and particle dispersion simulation tool for urban areas.

Our simulation system utilizes the unique computational parallelism afforded by 3D graphics hardware to run many simulations in an effort to train an optimization algorithm for determining optimal designs for urban structures and their layout. For instance, we might change a building’s location in the urban domain, change a building’s dimension while preserving volume, or change the material used to construct the building to provide more optimal pollutant dispersion while minimizing energy use. We accomplish this through our GPU-based environmental simulation software and its wind, energy, and dispersion modeling simulation modules. We also utilize an interactive and immersive virtual environment to provide unprecedented understanding and refinement of the complex physical processes associated with the energy balance and pollutant dispersion modeling in an urban setting [Pardyjak et al., 2009; Larson et al., 2009].

The basic equations for both our GPU wind and plume models are based on the Quick Urban and Industrial Complex (QUIC) dispersion modeling system [Pardyjak & Brown 2001; Williams et al. 2002]. The wind model, QUIC-URB, rapidly simulates time averaged winds within complex arrangements of buildings. The dispersion model is an unsteady “urbanized” random-walk model that contains a non-local mixing scheme and more drift terms than the traditional random-walk model in order to account for the turbulence inhomogeneity of urban flows. Our simulation system now uses NVIDIA’s CUDA API to compute mean wind fields and turbulence within an urban domain, and then simulate the dispersion of pollutants with the updated wind field. The speed up from doing these computations on the GPU allows our code to execute individual simulations from our optimization problems much more quickly than we originally expected. This poster highlights our current implementation.

Figure 1: Timing comparisons of three of our implementation variations on domains of size X = 512 x 21. The upper two series are an older comparison between a CUDA kernel using boundary compression and a CUDA kernel not using boundary compression. Part of the un-compressed version’s time advantage can be attributed to common denominator pre-calculation. The lower series represents times from our current implementation.

Figure 2: This figure shows the relationship between the different components of the QUIC simulation once fully implemented using CUDA. The urb portion of the simulation consists of both the wind and heat models along with a diagnostic visualization. The plume portion of the simulation consists of the dispersion model and the primary visualization for the user. The eventual goal is to have both parts run in conjunction in real time or run separately via the use of files to transport data.