Planning more resilient cities

Research Brief, Volume 2, 2017

PROBLEM

Over the past decade severe wind and storm weather conditions have cost the US an estimated $340 billion and resulted in 1,643 deaths. Of this, approximately $130 billion and 1,000 deaths are related to structural failure of buildings. Structural design codes imposed by the International Code Council (ICC) are specific to building type and geographical region. This approach works well in rural environments but not in urban areas where local building geometries have the potential to double wind loads. This poses a severe health and safety hazard and magnifies the risk of excessive repair costs. This brief examines how statistical tools can be utilized to capture the complexity of urban networks of hundreds of thousands of buildings and reduce them to models of tens of buildings. Wind flow simulations can be easily and efficiently applied to the smaller grouping, providing more accurate distributions of wind loads.

APPROACH

Researchers used Delaunay Triangulation—an approach used in graph theory to connect nodes in a network by maximizing the minimum angle inside a triangle with an objective of finding nearest neighbors—to extract local information for the network of buildings. For each local neighbor, researchers obtained the distribution of distances, values further enriched with the measure of the orientational degree of order between the buildings. Both sets have shown statistical characteristics distinctive of normal distribution for all three types of cities previously studied as part of the work on Urban Heat Island (characterized from least to highly ordered, respectively as “gas”, “liquid” and “crystals”).

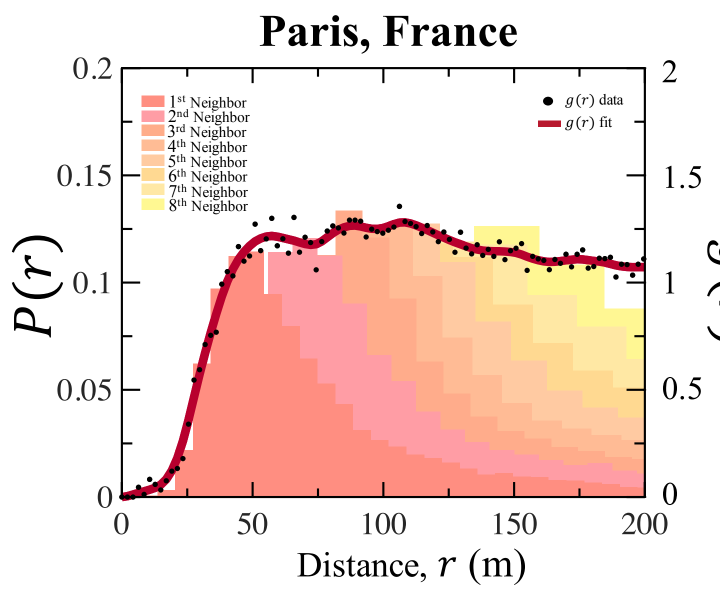

Fig.1: Probability distributions of distances, $P(r)$, for the first eight neighbors* obtained using the mesh data created using Delaunay Triangulation approach is juxtaposed with the radial distribution analysis, $g(r)$, of a “gas” city. The comparison shows that both approaches provide corresponding values for the shells of local neighbors, but only the DT method can differentiate individual neighbors.

*Eight was found to the appropriate number needed to create a sample of Paris.

FINDINGS

By incorporating the Delaunay Triangulation method for analyzing local network properties, researchers have refined their approach of generating statistical samples of cities. The dominant advantage of this modified technique over the previously employed $g(r)$ is its ability to extract local city characteristics in having no prevailing order “gas” cities—for highly chaotic in their structure “gas” cities (mostly present in Europe, i.e. Paris in fig.1) it is not possible to establish where the first and second peaks of the distribution are—allowing researchers to form a standardized approach for creating statistical models of cities. The next step for the researchers is to perform wind flow experiments on all three types of cities. The last step will entail analyses of refined samples that incorporate variation of building sizes, shapes and heights.

WHY DOES THIS RESEARCH MATTER?

- The approach proposed in this brief provides a simple and consistent way of creating city samples with tens of buildings that retain statistical characterizes of large urban networks of thousands of buildings.
- Small sample sizes enable wind flow analyses to obtain wind loads imposed on buildings in the city.
- This work supports the development of new building design standards that better capture wind flow in cities.

This research was carried out by the CSHub@MIT with sponsorship provided by the Portland Cement Association and the Ready Mixed Concrete Research & Education Foundation. CSHub@MIT is solely responsible for content. Authors: J. Sobstyl, R.-J. Pellenq, F-J. Ulm