What Big Data Tell Us About Trees and the Sky in the Cities

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Since Google Street View (GSV) was launched in 2007, its cars have been collecting millions of photographs in hundreds of cities around the world. In New York City alone, there are about 100,000 sampling points, with six photographs captured in each of them, totaling 600,000 images. In London, this number reaches 1 million images. The GSV fleet now also includes bicycles, trolleys (for indoor spaces), snowmobiles, and "trekkers" (for areas inaccessible by other modes). Using the images to fly over the Grand Canyon, visit historic landmarks in Egypt, discover national parks in Uganda, or circulate through the streets of Moscow, although great experiences, explore only the most immediate and visual aspects of the images. Such an overwhelming abundance of images becomes much more interesting when we consider them as a rich source of urban information.

Researchers in the fields of computer sciences and artificial intelligence have been applying computer vision and machine learning techniques to interpret GSV images. Very few of them move beyond the technical aspects of deciphering these images to explore novel ways to understand the urban environment. The few examples include the detection and counting of pedestrians (Yin et al. 2015) or the inferring of landmarks in cities (Lander et al. 2017). Still, most of this research is either based on small subsets of GSV data or presents a combination of techniques in which the participation of humans is required:

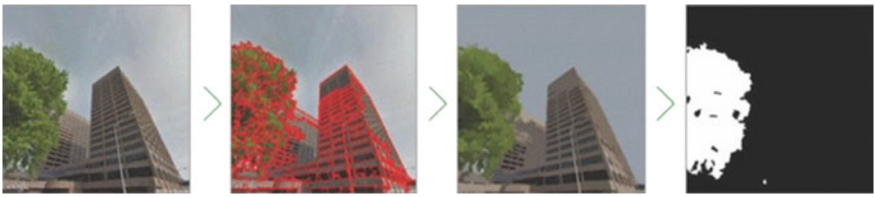

Fig. 1 Computer vision process

At the Senseable City Lab, we have been using computer vision and machine learning techniques to analyze full datasets of GSV images in order to understand urban features in ways that would take too long or be financially prohibitive for most cities using human-based or other technological methods. We started by looking at the trees and to the sky. Exposure to greenery and natural light is essential to human well-being,

K. De Rycke et al., *Humanizing Digital Reality*,
https://doi.org/10.1007/978-981-10-6611-5_6

outdoor comfort, and climate mitigation. Therefore, quantifying green areas and light exposure in different parts of the city will inform better urban design as well as environmental and public health policies. By using GSV data with computer vision techniques, we demonstrate the value of bringing big data to the human level, to the tangible aspects of urban life.

Usually, street trees are quantified and characterized using field surveys or other technologies such as high spatial resolution remote sensing. These techniques depend on intensive manual labor, specialized knowledge, and ad hoc data acquisition. Although satellite imagery analysis gives accurate quantification and characterization of green areas in cities, the technology has two critical caveats for urban dwellers: firstly, it looks at the city from above, not from a person's perspective. Satellite imagery does not show greenery at the street level, which is the most active space in the city and where people see and feel the urban environment. Secondly, larger green areas are highlighted in detriment to the relatively sparse street greenery. However, visits to parks and urban forests do not happen frequently and the benefits of these areas are felt at a large scale, whereas street trees are part of citizens' daily experience and have immediate positive effects on people's lives. We are not dismissing such techniques, but finding ways to take advantage of the huge amount of standardized visual data freely available of hundreds of cities to propose a human-centric and comparable assessment of street greenery.

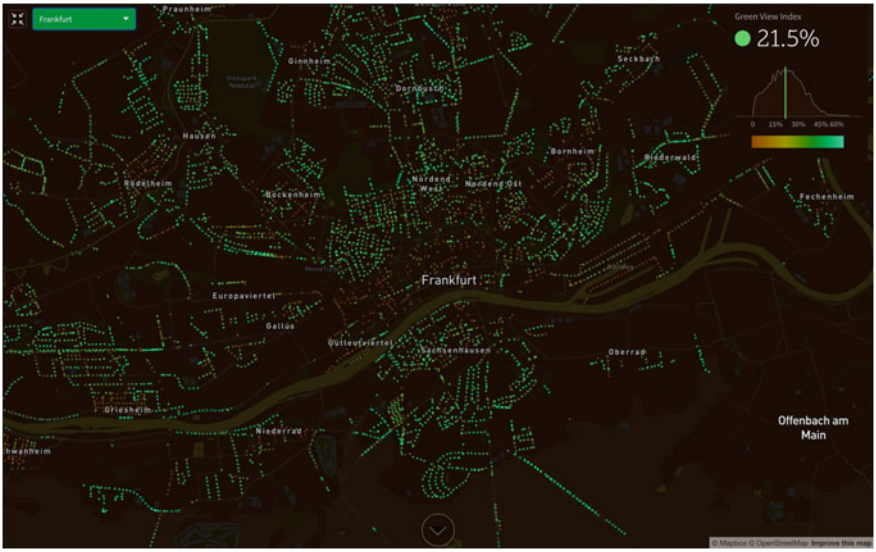

Fig. 2 Treepedia in Frankfurt

Using large GSV datasets composed of hundreds of thousands of images per city, Li et al. (2015) and Seiferling et al. (2017) calculated the percentage of green vegetation in streets, using computer vision techniques to detect green pixels in each image and subtract geometric shapes. With a few computational steps, what is left from this subtraction is greenery. Since the GSV data acquisition procedure is standard, these methods allow us to calculate street greenery in dozens of cities around the world and to compare them—using what we called the green view index.[1]

By avoiding the pitfalls of creating "algorithmic sorting of places" (Shapiro 2017), which automates the attribution of social values onto visual aspects of an image, the analysis of large visual datasets with the same computer vision techniques across different cities and countries has the power to become a civic tool, by which citizens can compare street greenery in different cities and neighborhoods and demand adequate measures from public authorities.

A recent work (Li et al. 2017) has applied similar techniques to measure the sky view factor in cities. The sky view factor is usually understood as "the ratio between radiation received by a planar surface and that from the entire hemispheric radiating environment" (Svensson 2004: 203), varying from 0 to 1. In cities, it can used to quantify the degree of sky visibility within urban canyons, by which one can infer the exposure to natural light in each site, for instance. A common technique to measure the sky view factor is to capture fisheye images with special cameras. Again, as this technique is time consuming—and therefore financially prohibitive for most cities—even when it is done, it usually covers only part of the city. We have been using computer vision algorithms to analyze GSV panorama images in order to optimize the process, cover the entire city, and make such analysis more accessible.

Besides using sky view factor as an indicator of local environmental conditions, at the Senseable City Lab we are exploring using it in order to optimize urban infrastructure. One example is optimizing energy-saving programs in public areas. Cities have been converting their traditional street lights into LED technology, which consumes less energy and save cities millions of dollars per year—the 26 million street lights in the USA consume more than $2 billion in energy, and the greenhouse gas emissions they generate is comparable to 2.6 million cars. However, in most cities, even in those converting streetlights to LED, unless lampposts are equipped with photosensors, all streetlights turn on automatically at the same time, in some cases varying daily according to the astronomical sunset. Applying computer vision techniques to analyze dozens of thousands of GSV images, we can determine the sky view factor at each data point and match them with the nearby streetlights. By accounting for buildings and trees blocking the adequate amount of lighting required in each point of the city, it would be as if we had hyperlocal sunsets close to each streetlight and could determine the optimal time to turn on the lights, which would save energy and money to cities at an aggregate level. Using this highly granular information, we could optimize existing infrastructures without adding another layer of devices, but rather by using data which is already available.[2]

The underlying research question is how not to take data at face value but instead by the intrinsic information they hold about how cities work and how citizens live in the urban environment. A GSV image is more than simply a combined photograph if you analyze it with the appropriate tools. In both cases discussed here—street greenery

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[1] Treepedia project is available at http://senseable.mit.edu/treepedia.

[2] We are grateful to Ricardo Álvarez and Xiaojiang Li for some of the ideas discussed here; and to Lenna Johnsen for revising the paper.

and sky view factor—it is possible to imagine that soon such large amount of visual data will be collected more frequently and in many more cities. Furthermore, with more sensors deployed in urban infrastructure, embedded in personal mobile devices, and soon in driverless cars, we can foresee all this data available in real-time maps, which will help to design actuations at the local level as well as enable the creation of worldwide urban dashboards that would show multiple cities in a comparative way. Making sense of the sizeable quantities of data that is already generated in and about our cities will be key to creating innovative approaches to urban design, planning, and management.

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