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TOWARD SMART DUST

by Jonathan Sun and Carlo Ratti, SENSEable City Lab

Democratizing human health data.

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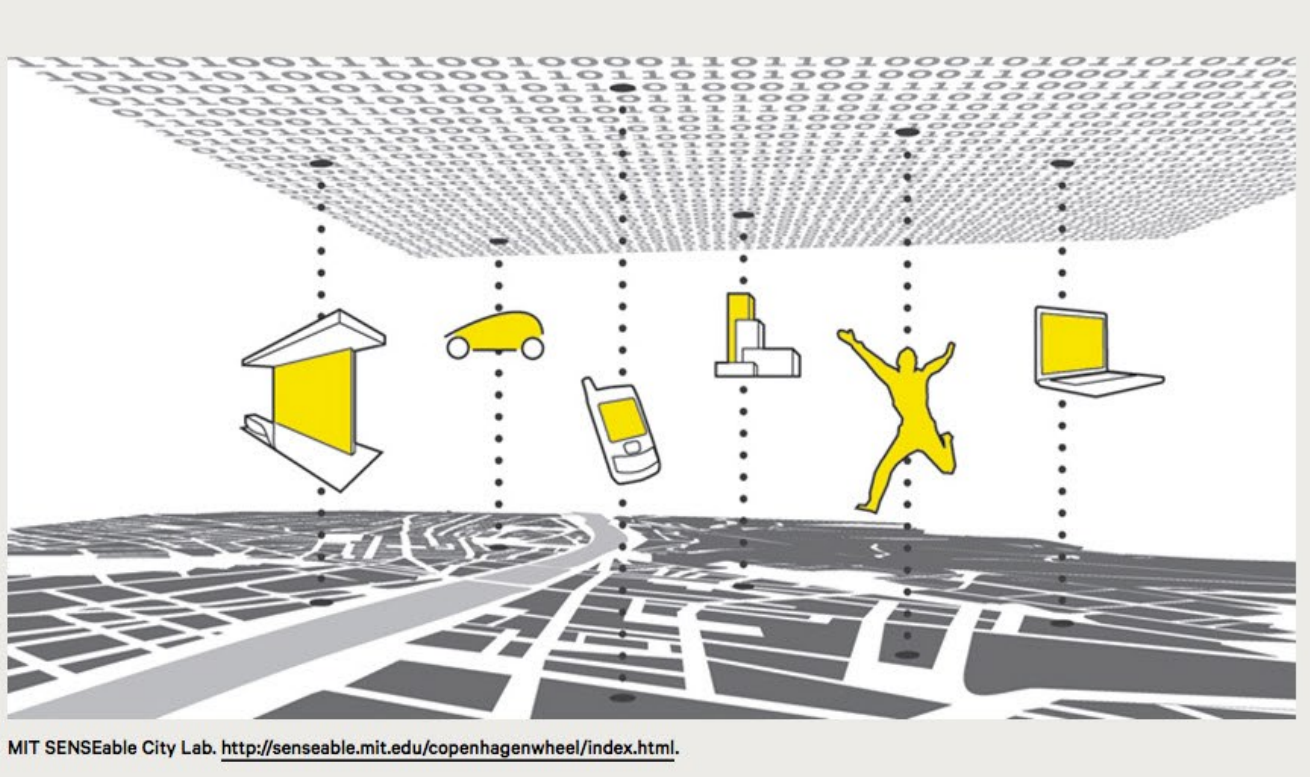
Cities are undergoing a profound transformation at the convergence of digital information (bits) and physical environment (bricks). As virtual systems become spatialized, our cities are being transformed into an "Internet of Things"—or better yet, an "Internet of Spaces." The inanimate physical environment is increasingly associated with a digital layer: code married to matter, physical brick to virtual bit. The city is becoming a physical companion to big data, the spatial infrastructure for digital information to proliferate.

The SENSEable City Laboratory at MIT operates at the intersection of bits and bricks. Due to the interdisciplinary nature of the city, we believe that the only way to study the city is through a similarly diverse team of researchers. Our team at MIT is comprised of around forty researchers, spanning a wide range of disciplines including architecture and design, policy and planning, computer and data science, physics, engineering, graphic design and visualization and social sciences. We work internationally, partnering with cities, governments, corporations and non-profit organizations to research, design and implement proof-of-concept projects in cities and sites all around the world.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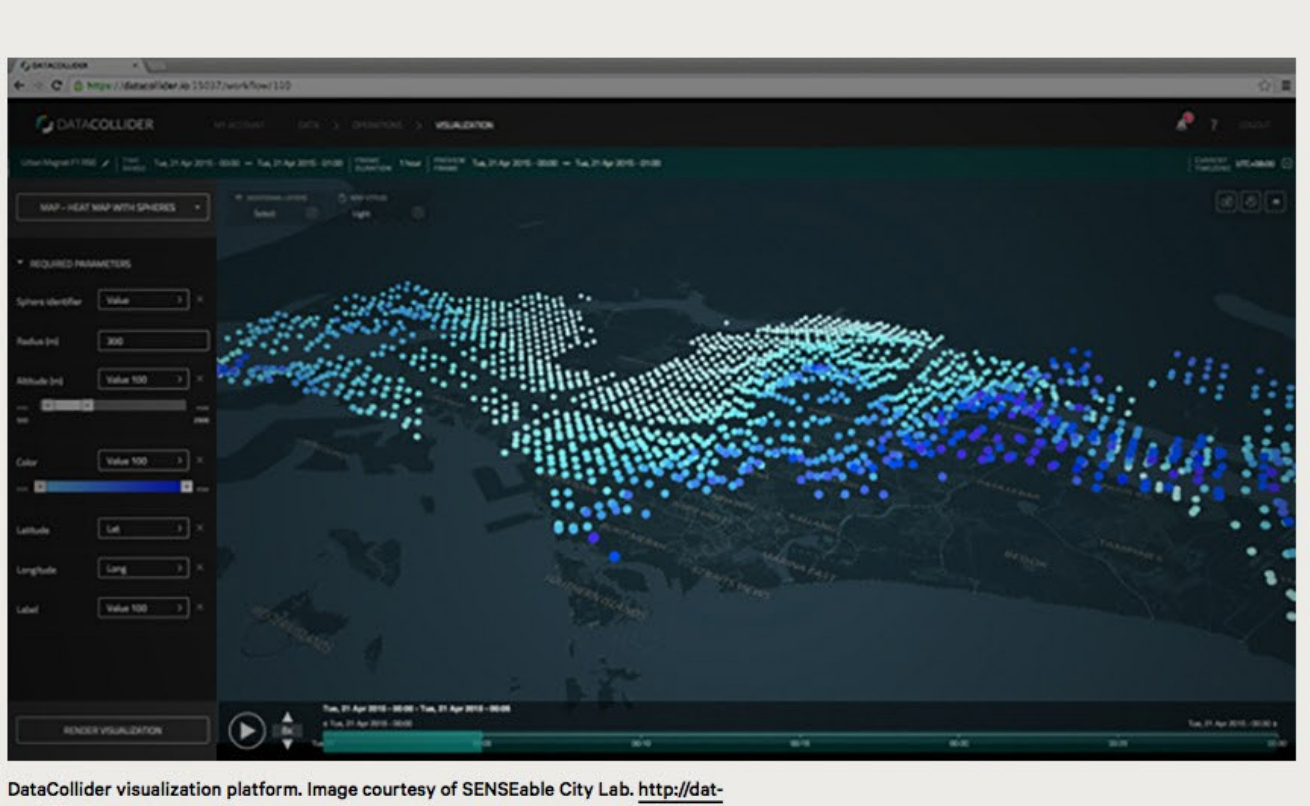
MIT SENSEable City Lab. http://senseable.mit.edu/copenhagenwheel/index.html.

By developing new digital and physical tools, and deploying them in the city, we aim to critically analyze urban phenomena. One of the trappings of urban data comes from analyzing it without truly understanding it first. To avoid this, we frame urban information with critical urban theory and scientific rigor, applying deductive theory to the often inductive approach to big data. Additionally, we aim to strengthen data literacy for the general public in the online design and presentation of our projects and findings. Our research therefore aims to democratize information and urban knowledge through accessible platforms—web-based tools that visualize urban data clearly and engage users to understand our work interactively. In other terms, data, or more accurately, the accessible presentation of our data-based research, is an "instrument of service" for architects and urban planners, which extends beyond the narrow realm of designer and client—the instrument, defined as the accessible knowledge platform, and the service, defined as the novel findings achieved through our work with urban sensors and data. We believe these instruments serve our collective body of knowledge and the city itself. The Lab plays with the scale at which such instruments are deployed and used, increasing the scope of both the service and the served. By doing so, urban-scale instruments serve not only a client, but also all the agents and players within and of the city—most importantly, the general public

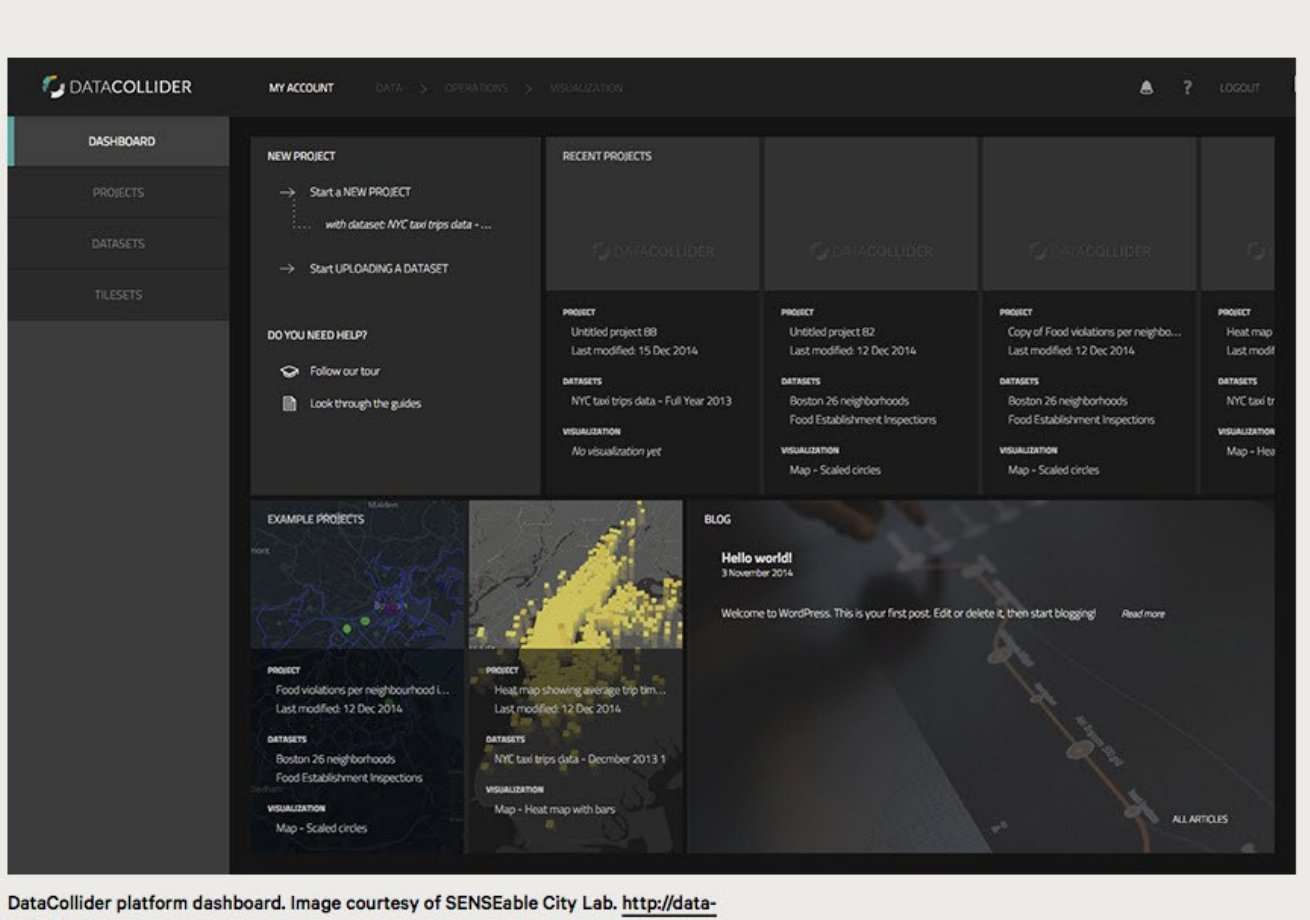
A common focus in our work is the health and well-being of citizens in urban environments. The projects that follow, DataCollider – AirScapes Singapore, The Copenhagen Wheel and Underworlds, illustrate three different directions from which we explore urban human health: data sharing and visualization, participatory sensing and the exploration of urban microbiome.


DATACOLLIDER
VISUALIZATION
MAP - HEAT MAP WITH SPHERES
REQUIRED PARAMETERS
Sphere Identifier
Radius (m)
Altitude (m)
Color
Latitude
Longitude
Label
RENDER VISUALIZATION

DataCollider visualization platform. Image courtesy of SENSEable City Lab. http://datacollider.io.

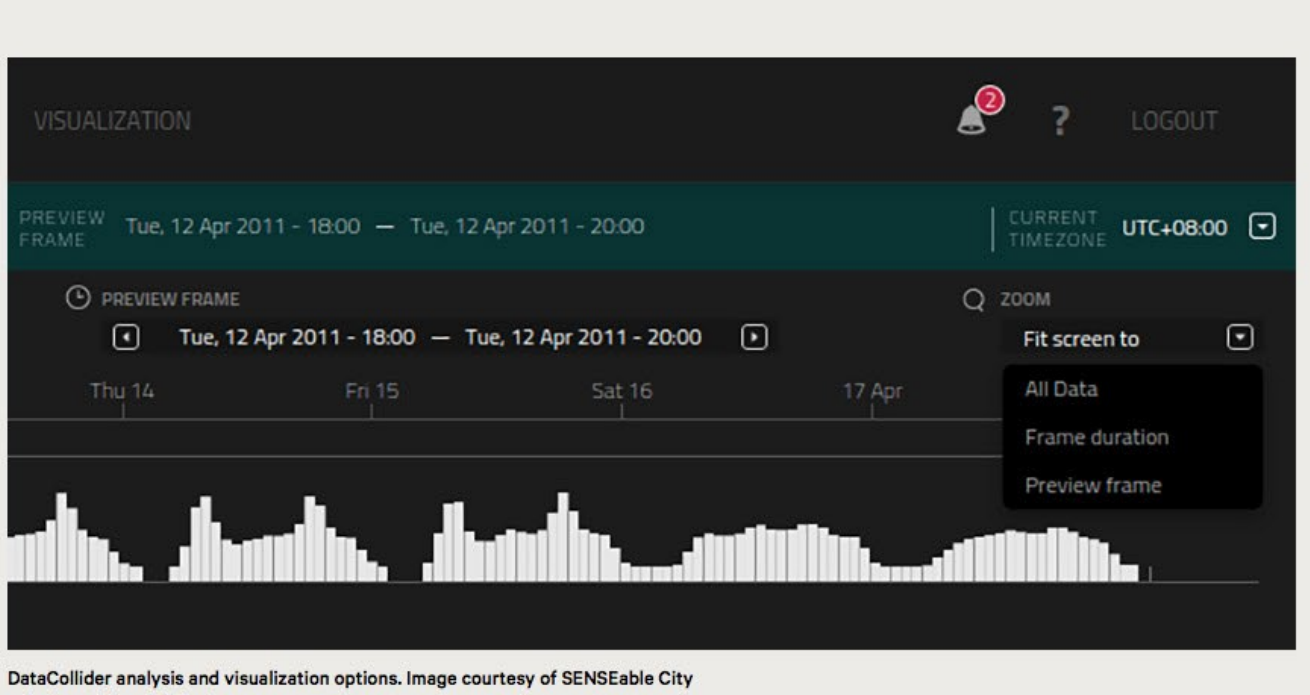
ON DATA SHARING AND VISUALIZATION

DataCollider, an ongoing project from our Singapore team, is a purely web-based platform for visualizing urban data. Created for public use as a tool to analyze data and generate visualizations efficiently and intuitively, it allows users to upload datasets in order to explore, present and understand the data easily.


DATACOLLIDER
MY ACCOUNT
DATA
OPERATIONS
VISUALIZATION
LOGOUT
DASHBOARD
PROJECTS
DATASETS
TILESETS
NEW PROJECT
Start a NEW PROJECT
with dataset: NYC taxi trips data - ...
Start UPLOADING A DATASET
DO YOU NEED HELP?
Follow our tour
Look through the guides
RECENT PROJECTS
EXAMPLE PROJECTS
BLOG
Hello world!
ALL ARTICLES

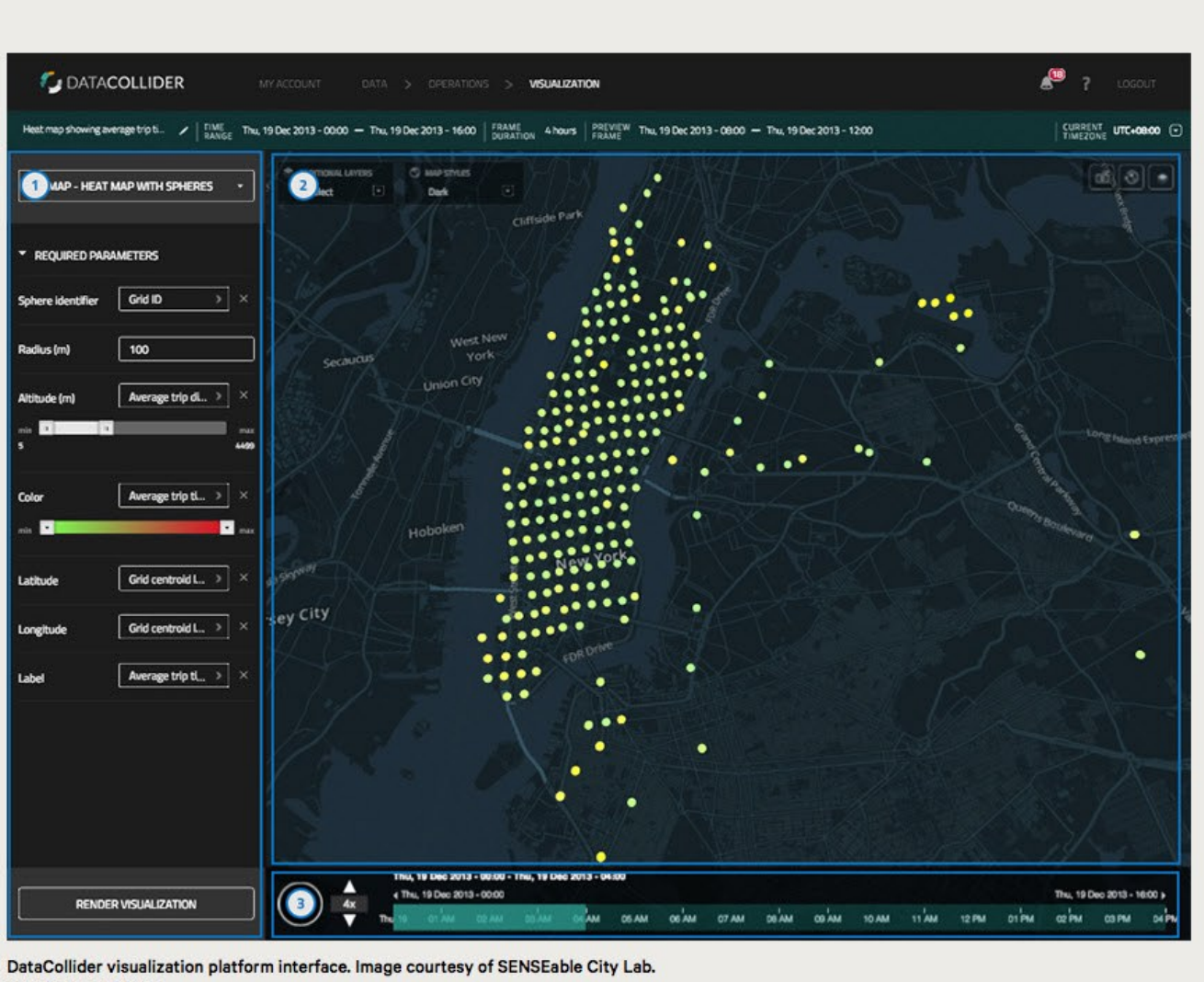
DataCollider platform dashboard. Image courtesy of SENSEable City Lab. http://datacollider.io.

Normally, data projects are an intensive undertaking in terms of resources—a significant commitment of time and people is required to make sense of large datasets. DataCollider aims to simplify and semi-automate this process in order to reduce the commitment needed to understand data, therefore making data research more accessible and democratic for the general public.


VISUALIZATION
LOGOUT
PREVIEW FRAME
Tue, 12 Apr 2011 - 18:00 — Tue, 12 Apr 2011 - 20:00
CURRENT TIMEZONE
UTC+08:00
ZOOM
Fit screen to
All Data
Frame duration
Preview frame
Thu 14
Fri 15
Sat 16
17 Apr

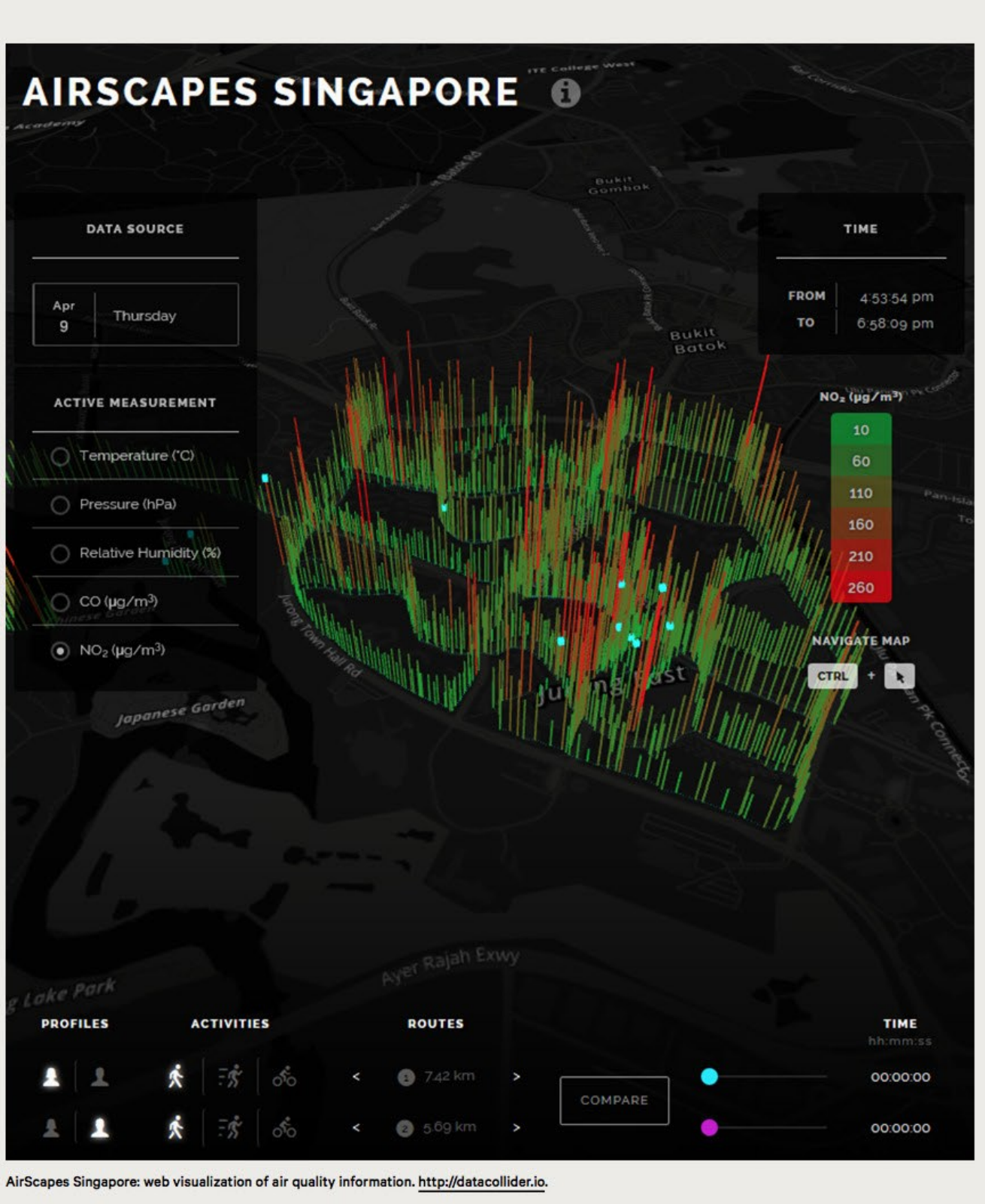
DataCollider analysis and visualization options. Image courtesy of SENSEable City Lab. http://datacollider.io.

This platform has widespread applications. It can work with any geo-spatial data (including transportation, behavioral, energy, financial and social media information) and, as a data tool, generates high-quality, interactive data visualizations—therefore acting as an interface between raw data, the user/the designer and the client/the served. Our own research uses the DataCollider platform as a visualization tool for the urban sensing projects we perform and analyze.


DATACOLLIDER
MAP - HEAT MAP WITH SPHERES
REQUIRED PARAMETERS
Sphere Identifier
Grid ID
Radius (m)
100
Altitude (m)
Average trip di...
Color
Average trip ti...
Latitude
Grid centroid l...
Longitude
Grid centroid l...
Label
Average trip ti...
RENDER VISUALIZATION

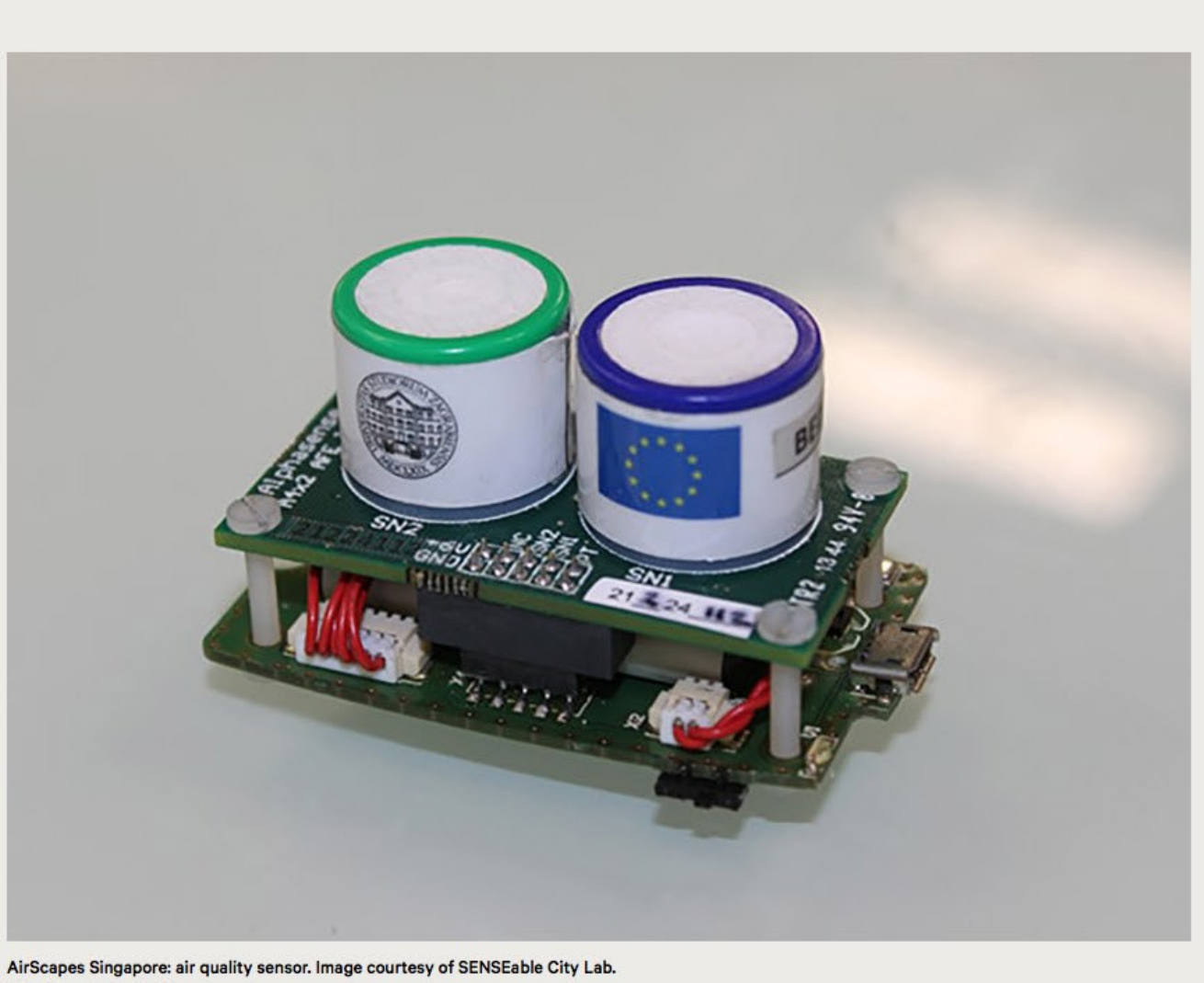
DataCollider visualization platform interface. Image courtesy of SENSEable City Lab. http://datacollider.io.

Our latest case study that uses this platform for visualization is the AirScapes Singapore project. With air pollution now recognized by the World Health Organization and the United Nations Environment Program as the world's single largest environmental and human health threat, the project explores the potential of a distributed network of moving sensors that monitor urban air quality in real-time through participant sensing.[1]


AIRSCAPES SINGAPORE
DATA SOURCE
Apr 9
Thursday
ACTIVE MEASUREMENT
Temperature (°C)
Pressure (hPa)
Relative Humidity (%)
CO (μg/m³)
NO₂ (μg/m³)
TIME
FROM 4:53:54 pm
TO 6:58:09 pm
NO₂ (μg/m³)
10
60
110
160
210
260
NAVIGATE MAP
CTRL
PROFILES
ACTIVITIES
ROUTES
7.42 km
5.69 km
COMPARE
TIME
00:00:00
00:00:00

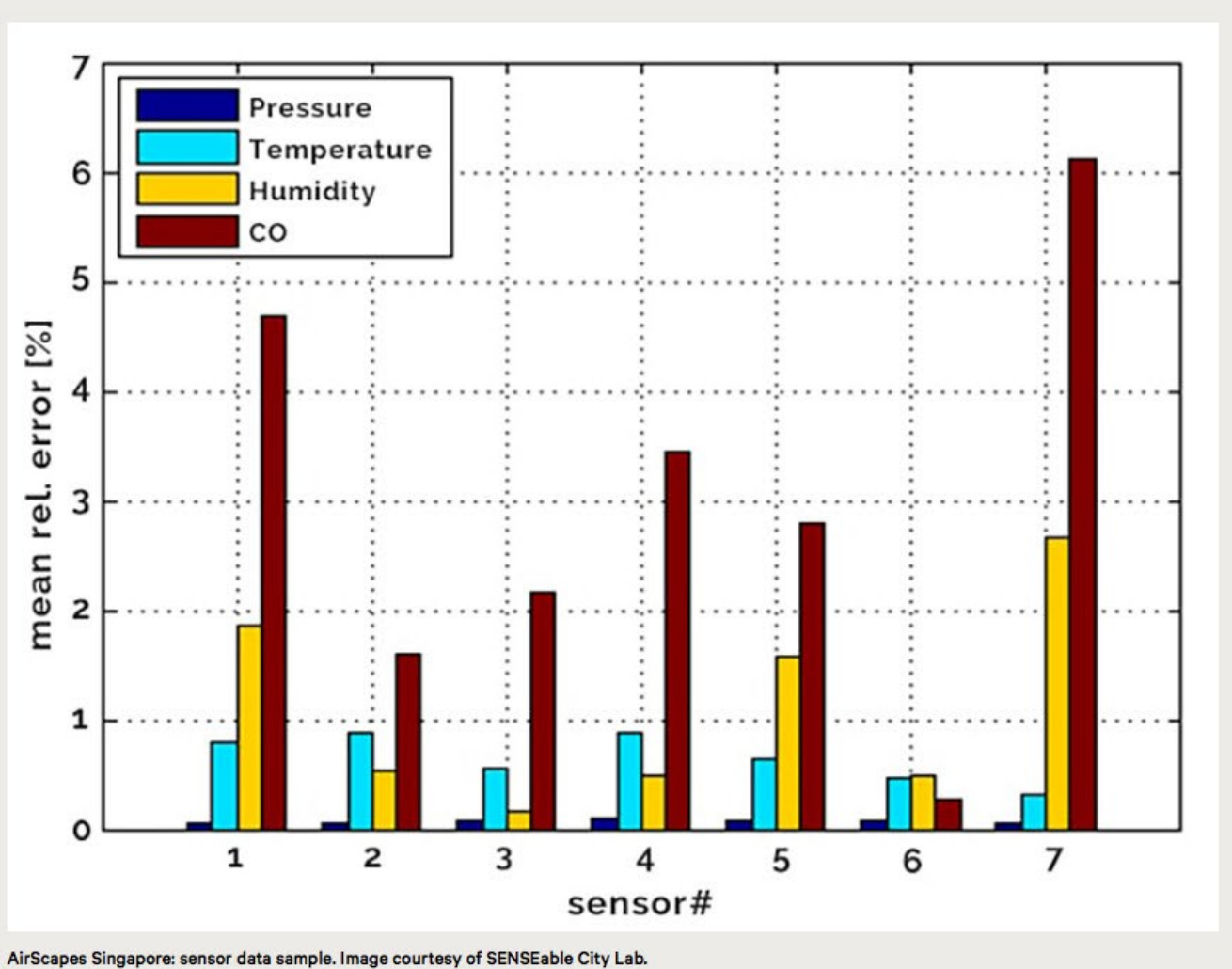
AirScapes Singapore: web visualization of air quality information. http://datacollider.io.

Air quality has been typically measured on an urban scale using sparsely located yet highly accurate monitoring apparatuses—devices that are not only expensive to set up and run, but also only yield data in low spatial resolution. As a result of these limitations, pervasive and ubiquitous air quality sensing (i.e. using a larger number of small sensors in space) has gained traction in recent years. A higher spatial resolution leads to more precise and localized solutions, including the ability to identify different causes of pollution and monitor the resulting health effects within these areas.



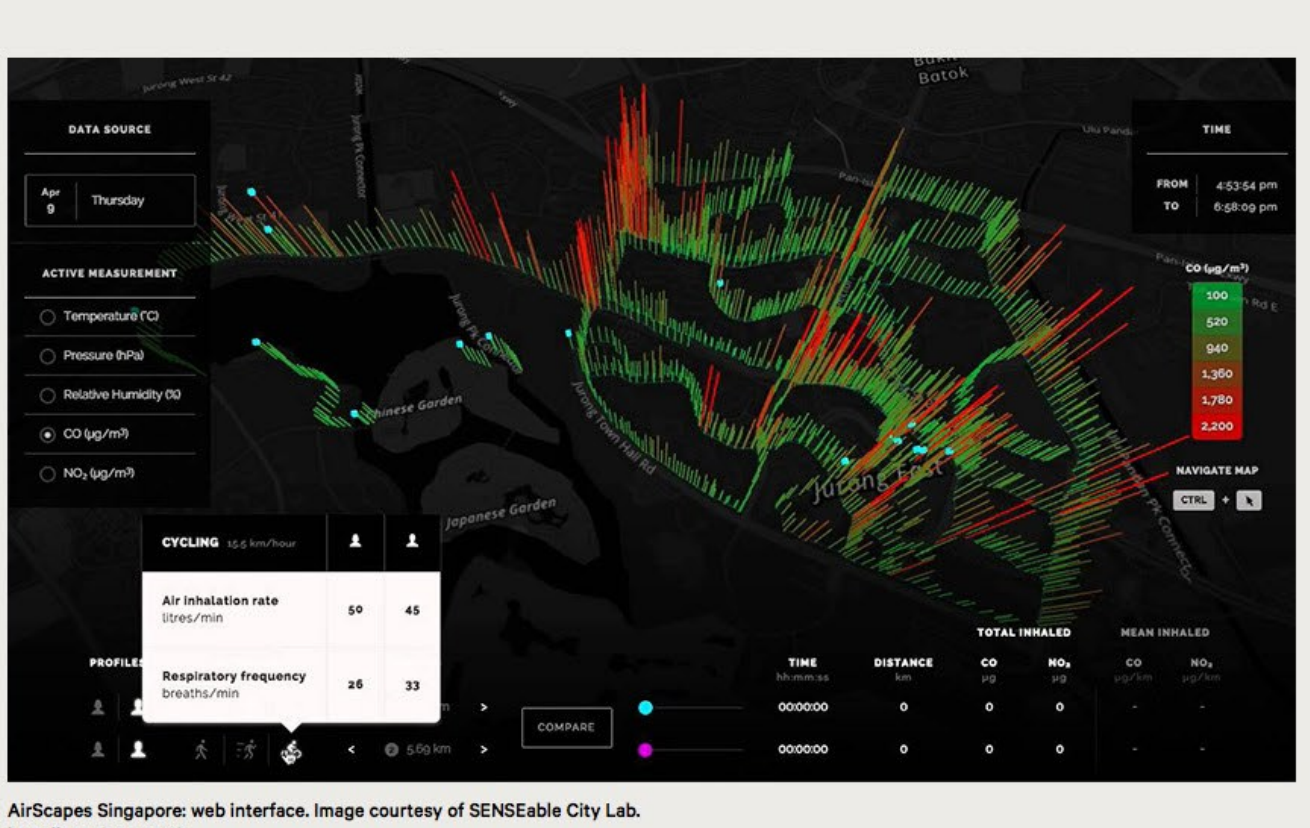
AirScapes Singapore: air quality sensor. Image courtesy of SENSEable City Lab. http://eoe.airscapes.io.

Forty participants were recruited in Singapore to conduct participant-based air quality monitoring using sensors connected to their smart-phones. Trials were conducted for ten successive days in April 2015. Nitrogen dioxide (NO2), carbon monoxide (CO), relative humidity (RH), temperature and pressure were measured every twenty seconds, along with their corresponding location.



AirScapes Singapore: sensor data sample. Image courtesy of SENSEable City Lab. http://eoe.airscapes.io.

Using DataCollider, a web-based platform was developed to display the collated air quality and meteorological data in real-time. This visualization of collected data allows people to see the air quality of different areas throughout the city and to understand the air quality in areas they frequent daily. Knowing where air quality is worst in the city, citizens could potentially change their behavior to minimize the exposure to and impacts of air pollution—and perhaps put pressure on the government to take citywide action to improve air quality. The research and the resulting data tool is then used not only by the city to understand spatial pollution distribution, but also by the general public to provide accessibly air quality information.

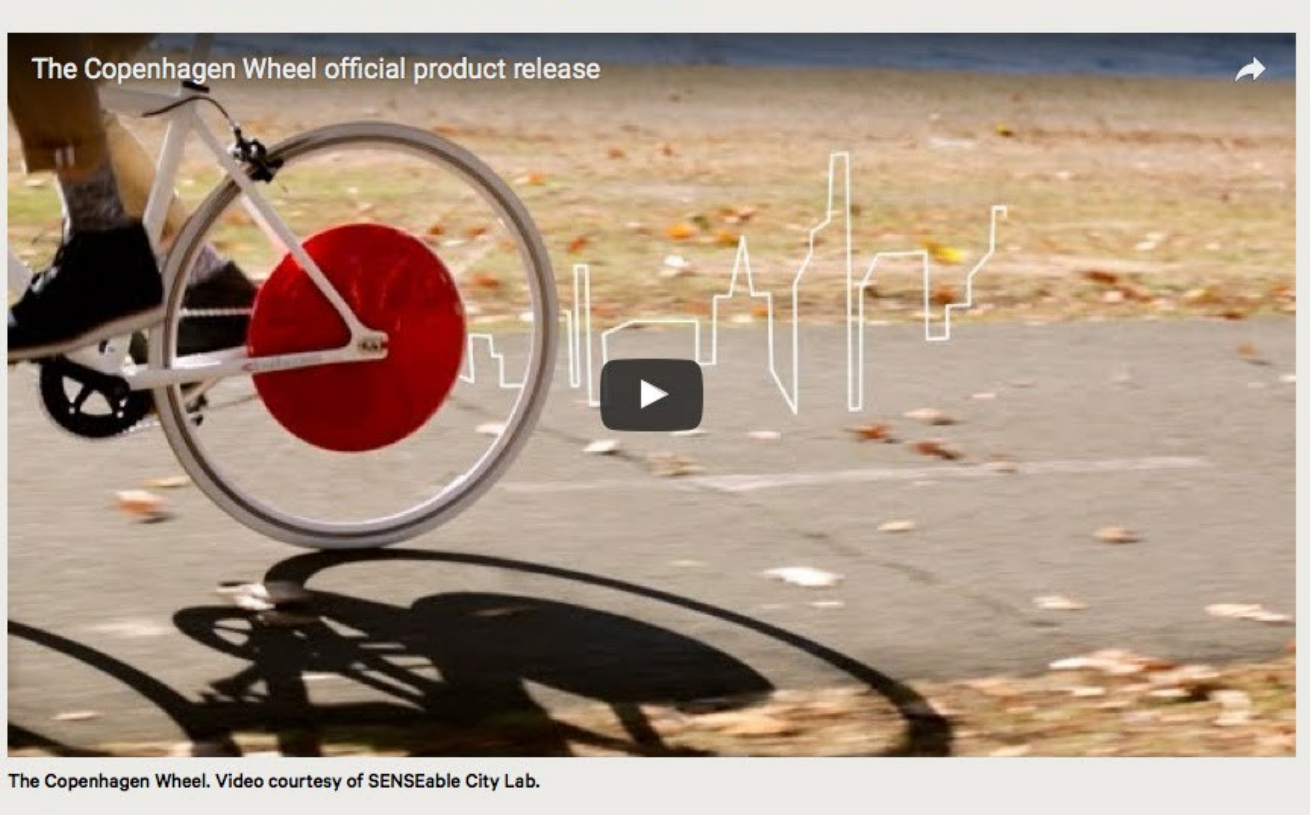

DATA SOURCE
Thursday
ACTIVE MEASUREMENT
Temperature (°C)
Pressure (hPa)
Relative Humidity (%)
CO (μg/m3)
NO₂ (μg/m3)
CYCLING
Air inhalation rate
Respiratory frequency
TIME
DISTANCE
CO
NO₂
TOTAL INHALED
MEAN INHALED
COMPARE
NAVIGATE MAP

AirScapes Singapore: web interface. Image courtesy of SENSEable City Lab. http://eoe.airscapes.io.

At this point, the study demonstrates a proof-of-concept for the collection of air quality and meteorological data in high spatial and temporal resolution using a distributed network of environmental sensors, as well as the design and implementation of a live display of aggregated data on a web application. The data collected from the study is currently being analyzed in the context of other data-sets collected in the vicinity of the site, such as information related to traffic mobility and public transportation, in order to study the correlation between transportation behavior and air quality.

ON PARTICIPATORY SENSING

While sensors are commonly deployed through top-down, city-based infrastructure, much of our work relies on the opposite: bottom-up, participant-based sensing. The idea of participant sensing is to give the individual a sense of responsibility and contribution—a strategy that is important in building trust between government agencies and its citizens, and thereby creating systems that will implement real change. When citizens contribute meaningfully to sensing studies they are able to develop a sense of ownership and commitment to the data being collected, which in turn creates a degree of trust and understanding with the agencies performing the study.


The Copenhagen Wheel official product release

The Copenhagen Wheel. Video courtesy of SENSEable City Lab.

The Copenhagen Wheel is an electric motorized bicycle wheel that transforms ordinary bicycles into hybrid e-bikes, and takes advantage of the participant-based sensing model. In an earlier version as a research prototype, the wheel also functioned as a mobile sensing unit, collecting data and mapping out pollution levels, traffic congestion, environmental data and road conditions in real-time.

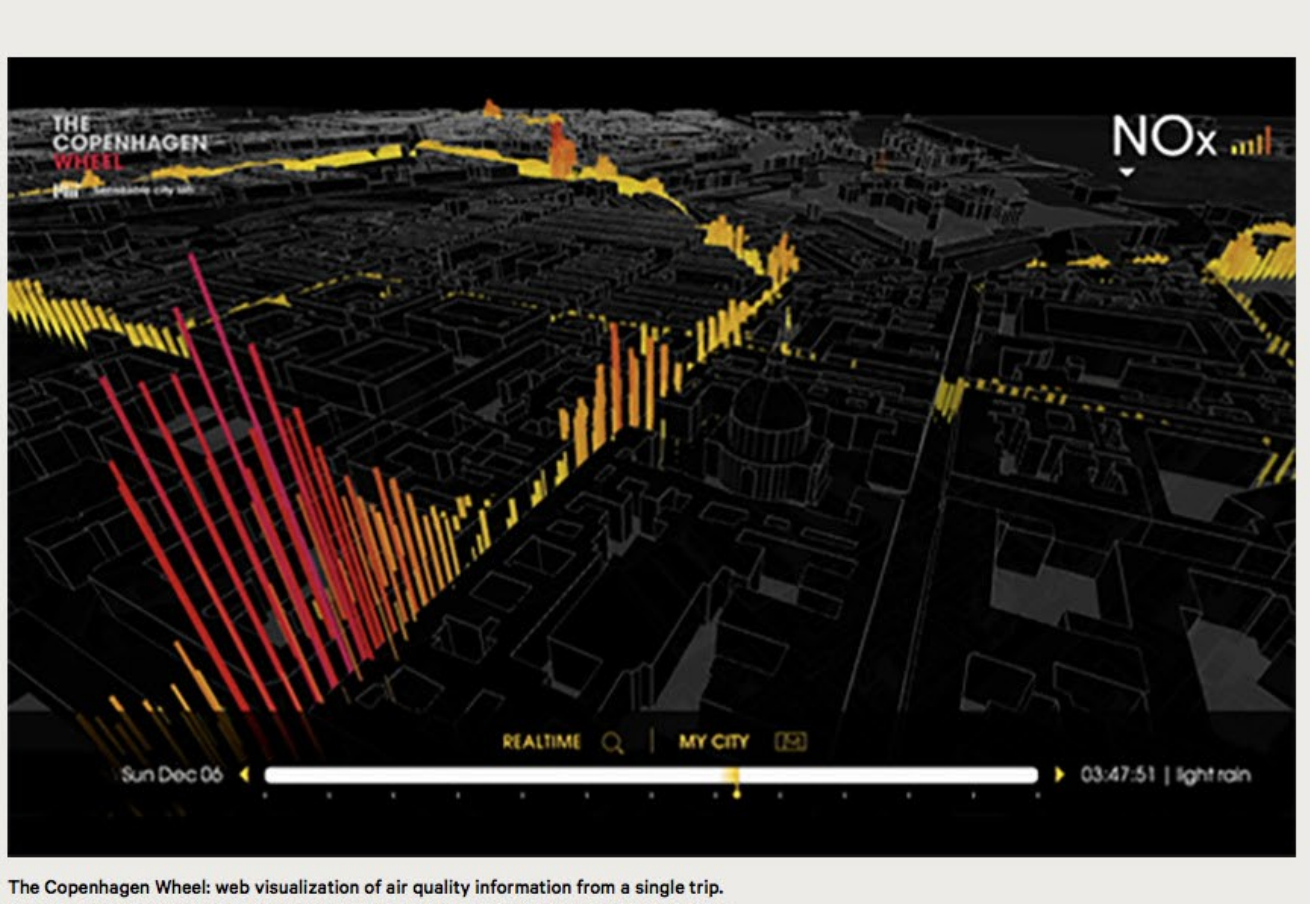
The Copenhagen Wheel. Image courtesy of Max Tomasinelli. http://senseable.mit.edu/copenhagenwheel/index.html.

The project was conceived and developed by the SENSEable City Lab for the Municipality of Copenhagen. The prototype bikes were realized with the help of our technical partner Ducati Energia and with funding from the Italian Ministry for the Environment.

The Copenhagen Wheel - Teaser

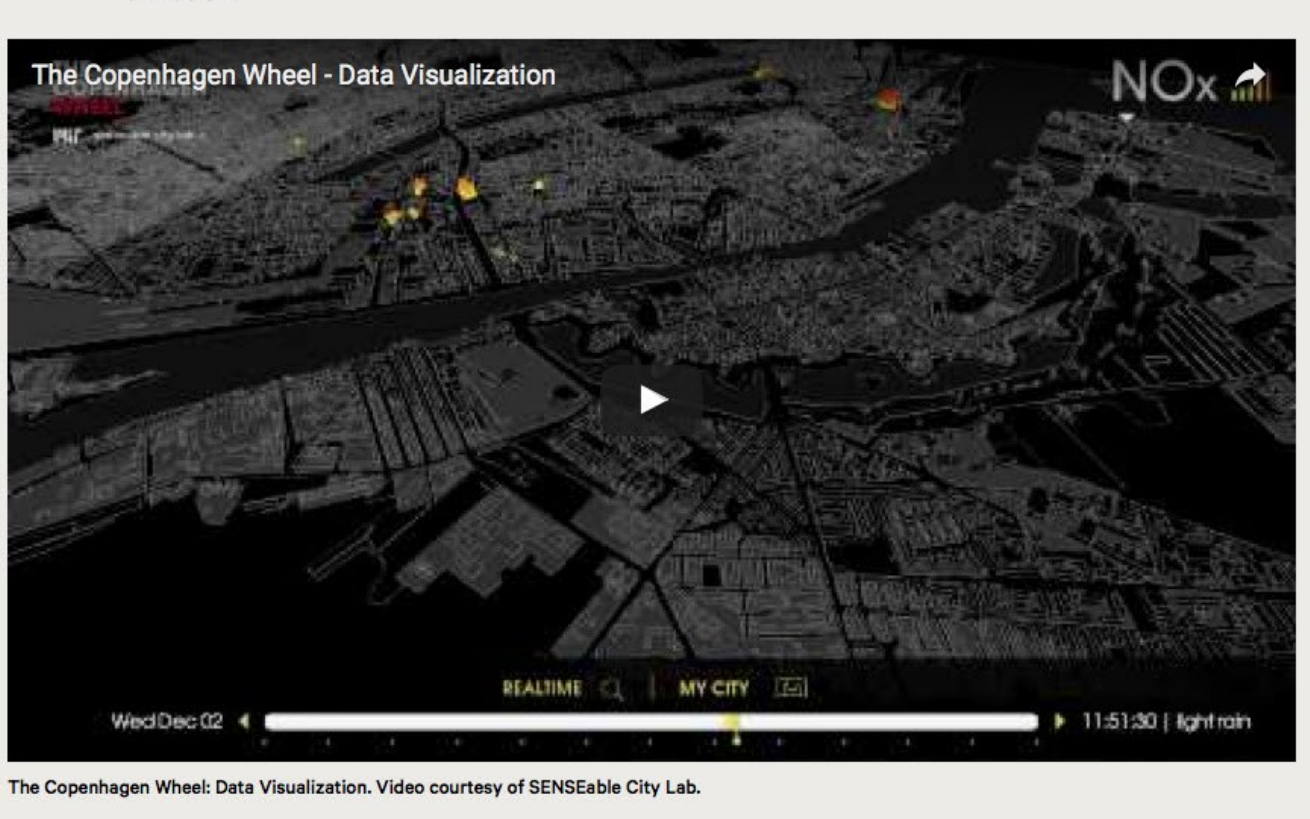
The Copenhagen Wheel: concept video. Video courtesy of SENSEable City Lab.

As a participatory sensing tool serving the citizen and the city, the prototype unit captured environmental and user information, such as air quality, travel time and route. This information was visualized so that the user could use it to plan healthier bike routes and achieve individual exercise goals. The information could also be shared with the city anonymously as a way to improve urban health and well-being. Moving beyond the research prototype phase, the Copenhagen Wheel is being developed for market by a new startup, Superpedestrian. While it will not initially contain sensing capabilities, it is being developed with the potential for this addition in the future.


THE COPENHAGEN WHEEL
NOx
REALTIME
MY CITY
Sun Dec 06
03:47:51 | light rain

The Copenhagen Wheel: web visualization of air quality information from a single trip. Image courtesy of SENSEable City Lab. http://senseable.mit.edu/copenhagenwheel/index.html.

In these participatory sensing models, public participation is key. What is significant about the wheel is that it serves primarily as a service-based product: it provides cycling and transportation benefits to its users. As a functional service, the electric wheel or the sensing platform might be adopted by a large number of users who would not otherwise participate in a sensing-based project. By coupling a sensing platform with a service, we are able to deploy more sensors and obtain a higher resolution of urban and environmental information.


The Copenhagen Wheel - Data Visualization
NOx
REALTIME
MY CITY
Wed Dec 02
11:51:30 | light rain

The Copenhagen Wheel: Data Visualization. Video courtesy of SENSEable City Lab.

ON THE EXPLORATION OF NEW URBAN FIELDS

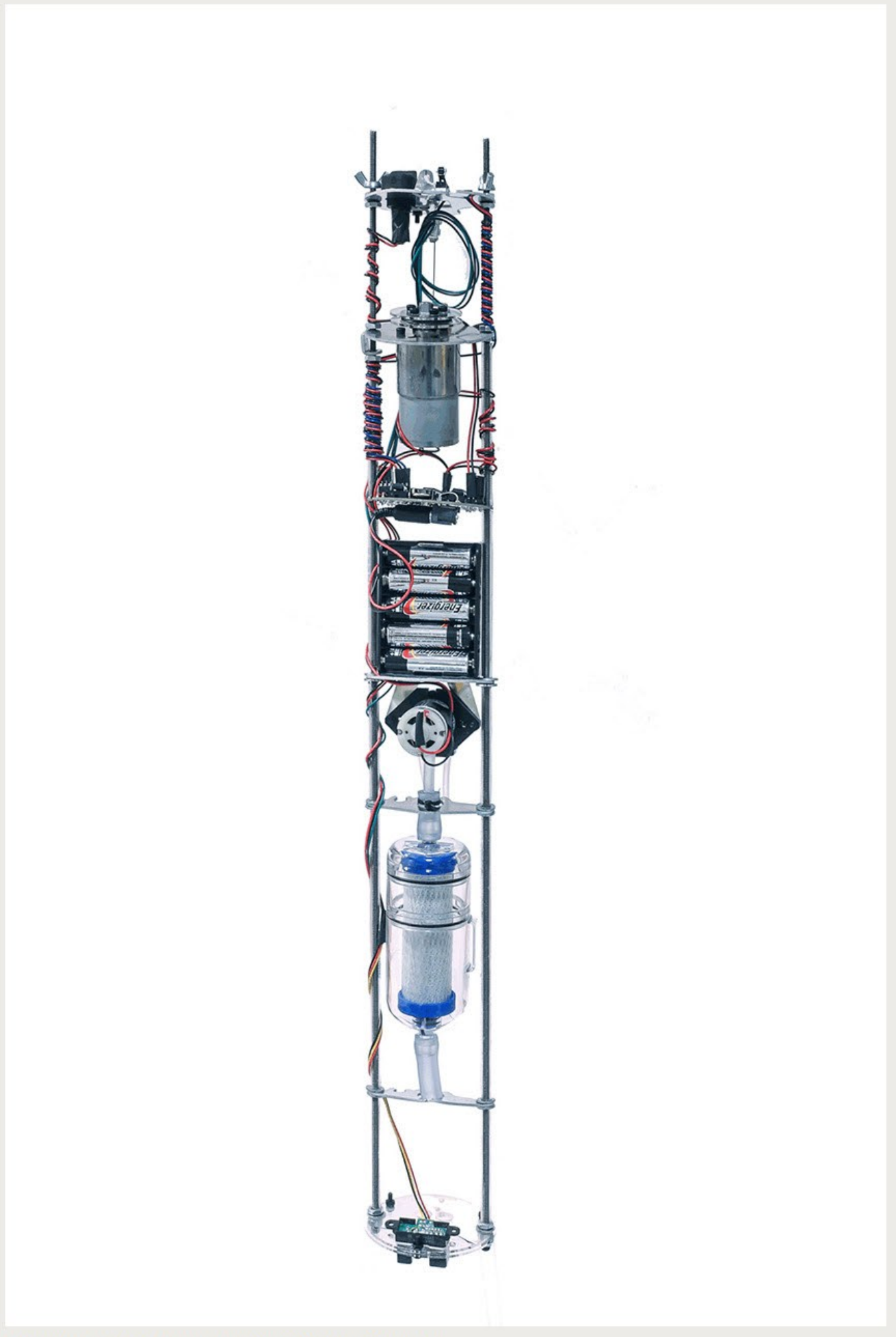
As we aim for an urban-scale approach to health and well-being, we must move past existing streams and areas of urban research and into new arenas.

In a recent report from the World Economic Forum on the Top Ten Urban Innovations, smart sewage and water management is listed as the second most innovative solution.[2] Population growth, ecological threats and climate change make it essential to manage water. The report calls for the use of sensors in network pipes to do so.

WHAT IS IN OUR COLLECTIVE GUT?
INFLUENZA
E.COLI
ESOMEPRAZOLE
NOROVIRUS
CAFFEINE
COFFICILE

Underworlds. Image courtesy of SENSEable City Lab. http://underworlds.mit.edu.

Underworlds imagines a future of smart sewage—a future in which sewage is mined for real-time information on human health and behavior. The project proposes a platform consisting of sensors in sewage pipes, in order to analyze bacteria and virus information from sewage water. By deploying sewage collection units, which perform real-time data analysis, the Underworlds project is the first of its kind: a proof-of-concept that cities can use sensors as an instrument of service in waste water systems to carry out real-time urban epidemiology, and to understand human health and behavior with a fine spatio-temporal resolution.

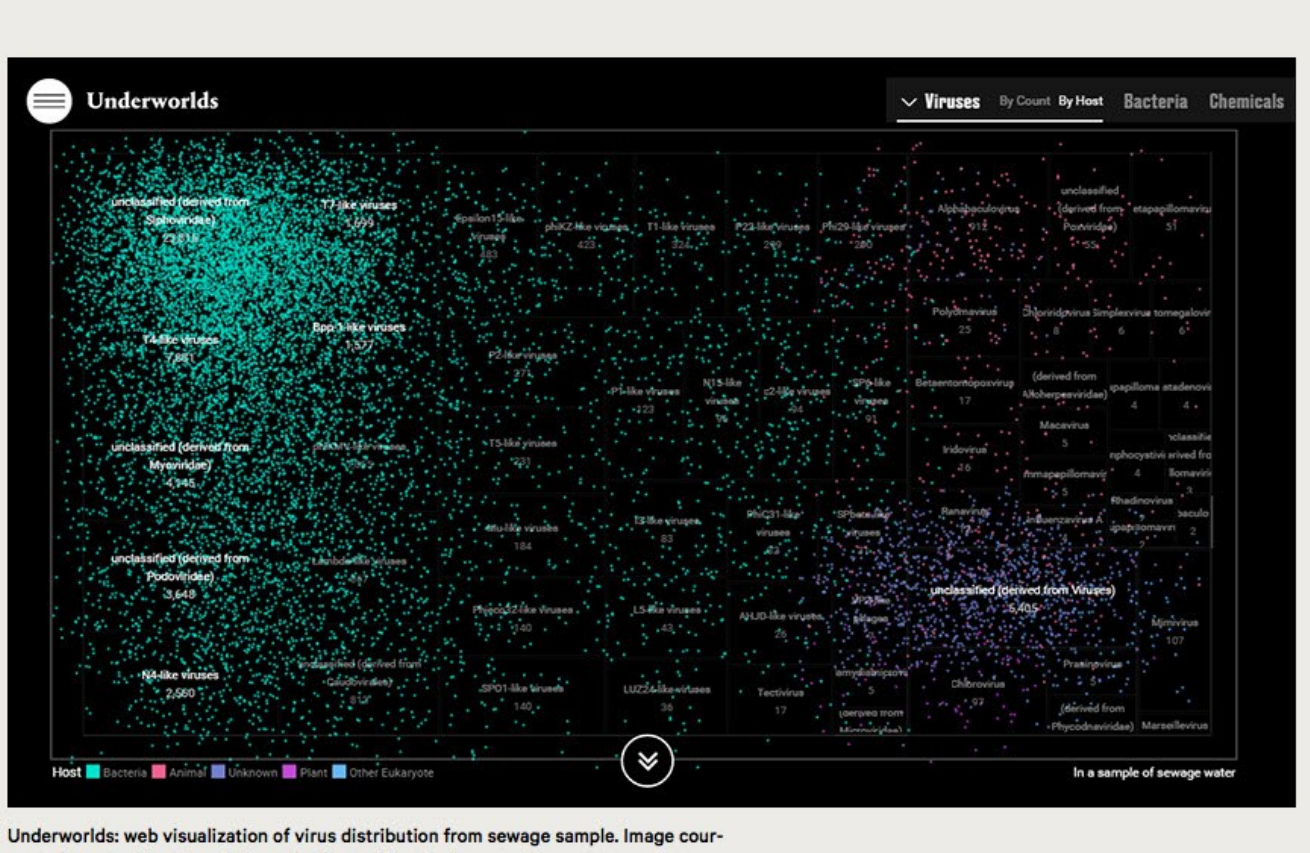


Underworlds: Luigi robot schematic. Image courtesy of SENSEable City Lab. http://underworlds.mit.edu.

Underworlds has currently been developing smart sensor robots and deploying them in MIT campus manholes across Cambridge. Filtered sewage samples are being analyzed and biochemical data extracted in parallel at the MIT Alm Lab.

Underworlds: Luigi robot deployment. Image courtesy of SENSEable City Lab. http://underworlds.mit.edu.

The first round of sample data has been visualized as a distribution of different virus types found in the initial sample, including human-host viruses responsible for influenza, papilloma and chickenpox, as well as virus strains which infect E. coli bacteria. The next phase is to deploy a full network of sensors throughout a pipe network, and to make the resulting data accessible through a web-based interactive visualization.


Underworlds
Viruses
By Count
By Host
Bacteria
Chemicals
Host
Bacteria
Animal
Unknown
Plant
Other Eukaryote
In a sample of sewage water

Underworlds: web visualization of virus distribution from sewage sample. Image courtesy of SENSEable City Lab. http://underworlds.mit.edu.

We anticipate that the applications of this project include infectious disease surveillance, the prediction of outbreaks and census-level health surveying. Such early warnings could help to prevent pandemics, save lives and significantly reduce medical costs.

By focusing our research in areas and fields that have yet to be explored on an urban scale, we anticipate new ways to serve our cities and our citizens.

TOWARD A SENSEABLE CITY

Distributed sensors are becoming an integral component in our lives. Embedded in our phones, in our computers, in our cars and in our cities, these sensors gather and relay streams of data about the spaces that surround us and our behavior within them. As sensors get smaller and smaller, they can be integrated in every piece of ourselves and our environments—an invisible "smart dust:" networked, atomized, computerized micro-particles that enable space to sense, intercommunicate and activate.

Our aim is to interrogate urban health through a variety of different dimensions (data sharing and visualization, participatory sensing and the exploration of the urban microbiome) that utilize these smart dust technologies. The ultimate goal: to bring health to the forefront of ideas on the *SENSEable City*—the city that responds in real-time to information about its environment. These instruments serve the general public, and help envision a city of bricks and bits as a healthy city as well.

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[1] World Health Organization. "Health and the Environment: Addressing the Health Impact of Air Pollution." 2015. Resolution WHA 68.8, Agenda item 14.6. 68th World Health Assembly. Geneva: World Health Organization. http://apps.who.int/gb/ebwha/pdf_files/WHA68/A68_R8-en.pdf. ^

[2] Global Agenda Council on the Future of Cities. 2015. "Top Ten Urban Innovations 2015." Global Agenda REF 191015. Geneva: World Economic Forum. http://www3.weforum.org/docs/Top_10_Emerging_Urban_Innovations_report_2010_20.10.pdf. ^

Jonathan Sun is an architect, designer, engineer, artist and writer. He is a doctoral student and researcher at MIT's SENSEable City Lab in the Department of Urban Studies and Planning. He holds a M.Arch from Yale and a BASc in Engineering Science from the University of Toronto. His work investigates perception and experience across multiple disciplines, and has been featured on NPR and The Independent.

An architect and engineer by training, Carlo Ratti is professor of the Practice of Urban Technologies at MIT, where he directs the SENSEable City Lab. He is also a founder of the International design office Carlo Ratti Associati. Carlo's work has been showcased in leading publications and exhibited globally, including the Venice Biennale and MoMA in New York. Wired Magazine featured him among "50 people who will change the world."

For full acknowledgements, please visit the project websites listed below.

DataCollider: datacollider.io
AirScapes Singapore: eoe.airscapes.io
Copenhagen Wheel: senseable.mit.edu/copenhagenwheel; www.superpedestrian.com
Underworlds: underworlds.mit.edu

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Announcing: Issue 00 Cracker Jack, on strange and significant laboratories in the the history of research. bit.ly/1V3uNY4 .
Tue December 22, 2015 19:01