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SENSEable CITY GUIDE
TO AMSTERDAM
Welcome to the SENSEable City Lab – a cutting-edge multidisciplinary research group that studies the interface between cities, people, and technologies and investigates how the ubiquity of digital devices and the various telecommunication networks that augment our cities, are impacting urban living. With an overall goal of anticipating future trends, we bring together researchers from over a dozen academic disciplines to work on groundbreaking ideas and innovative real-world demonstrations.

Each academic year, the SENSEable City Lab invites students at the Massachusetts Institute of Technology to participate in the Digital City Design Workshop. The workshop seeks to provide pragmatic, technological solutions that address a key concern of urban living. The SENSEable City Guide series showcases this research which is undertaken in partnership with cities from across the world.
Street lights are a key piece of urban infrastructure for cities around the world. For centuries cities have been placing lamps on their streets in order to provide light to their public spaces and in a sense conquer the darkness of the night. It is in part because of street lights that life in cities flourish after sundown; that streets are safe, parks are filled with people and commercial activity continues.

However, this comes at a cost. Street lights account for up to 40% of cities energy consumption and are a known cause of light pollution, as such there is a pressing need to improve them. Given that there are more than one billion street lights around the world, this is a monumental endeavor.

Amsterdam, city of canals, the Venice of the North has a long history with street lights. It is here that Jan van der Heyden installed one of the first street lights systems in Europe in 1669 and invented a breakthrough lamp which channeled the smoke from oil lamps upwards cleaning the air around them and keeping their glass free of soot, a critical invention that helped multiply the adoption of street lamps around the world; within a few decades these lamps were installed by cities such as Paris, London or Paris.

Street lights in Amsterdam are also a true architectural delight, creating decorative fixtures that bring beauty to its streets and façades and provide a warm light glow that gives character to its public spaces. The city is proud of both its artistic and technological heritage in regards to street lights and every year holds the Amsterdam Light Festival, which showcases artistic and technological innovations from many light artists from around the world and welcomes more than 750,000 visitors every year.

For the spring 2015 Senseable City Lab’s Digital Design Workshop class were given the task of reimagining the street lights of Amsterdam leveraging the potential of digital technologies.

What other uses for a such a relevant piece of urban furniture could be created? In which ways could street lights improve the lives and conditions of the citizens and visitors of Amsterdam? This was their design challenge. In preparation for this work the students took a deep dive into the current technological state-of-the-art intelligent street lights being deployed in cities around the world and then challenged the possibilities of their design.

This book showcases the creative output from the team, developed as a result of their field worked in the city and their design explorations of street lights both as functional objects and urban system, and their potential for creating new services and experiences for Amsterdammers to enjoy.

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sensation during winter time that enhances the livability and walkability of the beautiful streets alongside the canals and other districts of the city.

“Sterrennacht" by Charles Steelman actually proposes to regain a bit of the night sky, lost by way of light pollution. He envisions a future network of street lights paired with a series of sensors such as photometers, digital image sensors and image processors capable of detecting pedestrian behaviors on the streets and mapping accurate light and color conditions at a hyper-local level while leveraging a control system intelligent enough to modulate the light output from each individual LED powered street light according to a variety of spatial and use profiles. Through his design, Amsterdam could create ideal illuminating conditions that allows its citizens to enjoy both the advantages that a street light provides as well as being able to enjoy the beauty of a starry night, a condition often lost from our modern metropolises.

“Share the Shine” from WenlingLi on the communication platform capable of guiding and dynamically distributing the thousands of tourists that everyday visit Amsterdam and who often crowd many of the most popular destinations in the city such as the train station, the red light district or the Rijks Museum. His “Guiding Light” project will create an interactive loop between tourists smartphones and geofenced responsive lights that links the content of Amsterdam to the particular interests of users, guiding them away from the crowds and towards the rich history and culture of the city.

Meanwhile Myung Duk Chung designs a playful street light that “hugs” passerby’s with warmth. His “Hugging Light” proposal integrates a series of digital image and proximity sensors along with the use of computer vision technologies and an automated array of infraredmicro-heaters embedded in the streetlight frame. The purpose of these technologies is to provide localized warmth that follows pedestrians as they walk through the streets of Amsterdam, creating a pleasant sensation during winter time that enhances the livability and walkability of the beautiful streets alongside the canals and other districts of the city.

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Verlichten
by Lily Bui
Though a vast majority of visually-impaired people live in urban environments, many are prevented from efficiently traveling in cities, especially true in unfamiliar areas. Solutions that are cognizant of sensory limitations of the visually impaired is clear in the statistics as well as in our site visit to Amsterdam. In interviews and meetings with city planners emerged an articulation of the desire design for social inclusion, to create spaces that enable and encourage socialization between different groups of people.

Problems of access and overcrowding provoke the question: how might we leverage existing technologies to help visually impaired pedestrians navigate overcrowded spaces? The solution may lay in public lighting.

Public lighting, one of Amsterdam’s major areas of investigation, is a ubiquitous form of infrastructure distributed throughout the city. While there are a number of projects that have launched to explore different use cases for exploiting light’s form — for instance, an “on-demand” lighting system called Twilight designed by Delft University of Technology — in which the street lights would only glow fully in the presence of a person, bicycle, or car — not much has been done to maximize on the lighting infrastructure’s pervasiveess in urban space.

The proposed “Verlichten” project involves maximizing on the ubiquity of urban lighting infrastructure as a location-based sensing platform to help visually impaired pedestrians safely navigate Amsterdam’s crowded spaces.

It uses 360 cameras deployed across the network of lighting infrastructure in order to monitor pedestrian, cyclist, and vehicle traffic on the sidewalk and road. The lighting infrastructure becomes a sensing platform wherein each pole’s camera locally senses its surroundings for people and vehicle traffic, generates data from low-resolution images, and relays the information to a mobile platform that can be used by visually impaired pedestrians. The system is responsive to the pedestrian’s location, creating a “safety bubble” around them, and it also pairs with smartphones and smart canes to convey information about potential hazards.

Because visually impaired pedestrians cannot see the screens of their smartphones, auditory and verbal features help with navigating the interface. The mobile platform is “speaks” to the pedestrian in real time as s/he proceeds along the commute, communicating information about oncoming pedestrian, cycling, or vehicle traffic. Visually impaired pedestrians can access this audio by way of smartphone or a smart cane. The pedestrian can make decisions about whether or not to continue on the path or to change routes and seek a less crowded path. The platform will be aware of the pedestrian’s location at all times as s/he enters the sensing radius of each light pole and communicate information about the pedestrian’s immediate vicinity.

The data that this platform generates can reveal meaningful patterns of mobility of the visually impaired urban population. It can also be used toward mapping the crowdedness of sidewalks and roads in public spaces over time. One can imagine this data being used
toward urban planning applications as well as everyday use by pedestrians who simply want to plan commuting routes based on foot traffic in certain areas. Local residents who would like more information about crowding in Amsterdam as well as tourists visiting from outside of the city can benefit from the data this platform generates.

Verlichten in Dutch means “to illuminate,” which can be read two different ways – both to irradiate a surface or to make something known and bring forth knowledge. The Verlichten platform employs the lighting structure to act as eyes on the street for those who cannot see.

As Amsterdam forges a path into a digitally-oriented future, a “design for all” approach in addressing overcrowding in the city ensures that this future will be one accessible to underserved populations as well as the general populi.

Right: urban light pole in downtown Amsterdam.
The Verlichten project addresses the gaps in existing technologies for the visually impaired. Within this system, even in the absence of a human guide, visually impaired pedestrians can use a mobile app enabled with voiceover to access information about pedestrian traffic.

At the beginning of a commute, the visually impaired pedestrian would open up the mobile app and leave it running. Along the commute, the Verlichten sensing platform will track where the pedestrian is in relation to the sensing grid. In especially crowded areas, the app will "speak" to the pedestrian in order to alert him or her about pedestrians, cyclists, or vehicles in the vicinity. For example, at a busy intersection, the app will tell the pedestrian if cars are approaching. In parks, which can be crowded yet relatively quiet, the app will tell pedestrians when cyclists or other pedestrians are nearby. The visually impaired pedestrian can then make decisions in real time about whether or how to alter his or her route. At the end of the commute, the pedestrian would simply close the app. Paired with a smart cane, the mobile app would also prompt the cane to play a vibratory signal in the direction of the hazard as an ancillary warning of obstructions. The cane is a natural interface for the visually impaired pedestrian, a vibratory signal makes use of an object that the pedestrian is already using to convey information.

Thus, when the pedestrian is walking in the city, the sensing platform deployed on the lighting system serves as the "eyes on the street" for those who are visually impaired.

While electronic aids for visually impaired pedestrians do exist, it is important to keep in mind that even a combination of non-visual sensory input will give a visually-impaired person an insufficient perception of space. Current electronic audio-based guides to cities require extensive training to use and are not consistent in design nor are they reliable. That place-based apps do not provide real-time feedback about space.

Interviews with individuals who have worked with visually impaired communities or are visually impaired themselves reveal some details about what information blind/visually impaired pedestrians expect on the street. The cognitive load that visually impaired pedestrians must pay acute attention to — street names, where the street is in relation to the sidewalk, number of lanes in the street, direction of traffic, when to cross the street, whether they are on the left or right sidewalk, nearby buildings and traffic light, etc. — is further complicated by having to navigate crowds of people, on top of also having to navigate nonhuman obstacles.
Above: a pedestrian constantly has a “safety bubble” around them, which activates nearby camera sensors. When potential hazards are present, the Verlichten platform communicates this to the pedestrian through audio on the mobile app.

The platform can also be synced with smart canes, which can vibrate as an ancillary alert to the pedestrian.
Amsterdam currently has accessible crosswalks that generate a sound audibly faster when it is safe for pedestrians to cross and more slowly when it is not. However, codified systems for visually impaired pedestrians are neither ubiquitous nor consistent in the Netherlands. In recent years, a “smart light” system has been installed at Hoekenrodeplein, a plaza in front of the Amsterdam ArenA, in order to experiment with how to use programmable lighting systems paired with sensors that detect pedestrians walking through the plaza and dim or brighten lights along their trajectory. This is one of the first steps toward using lighting as a sensing platform that could potentially be maximized for other sensing cases.

The Verlichten system would not only enable tracking types of crowds in real time, it would also allow for better accessibility of sidewalks for visually impaired pedestrians throughout the city. In effect, it creates a “safety bubble” for visually impaired pedestrians, providing a more secure way to navigate unfamiliar spaces.

Instead of having to rely only on cues in the built environment, Verlichten gives real-time feedback about the immediate environment via a more ubiquitous interface, a mobile phone and a cane.

The data that the Verlichten platform would collect data about the crowdedness of urban areas, which can potentially be repurposed toward urban mapping and planning as well as for similar crowd apps for the sighted population.

This initial design is specifically for the Knowledge Mile, an area in Amsterdam slated for development into an innovation district by 2018. It spans the length of Wibautstraat on the southeastern side of the city. Unlike downtown Amsterdam, the Knowledge Mile has wider sidewalks and can take a longer amount of time for pedestrians to walk from one block to the next. Most visually impaired people live and travel in such environments, making it an ideal test site. Each light will be “aware” of its vicinity and be able to relay that information to individuals with the companion mobile app or a smart cane.

Left: The Knowledge Mile is slated to be Amsterdam’s new innovation district by 2018.
Above: the pedestrian “safety bubble” activates the network of cameras the pedestrian moves through it.

Above: the Verlichten cameras detect pedestrians, cyclists, and vehicle traffic within the camera’s radius.
This system relies on these core components in order to function: a 360 camera mounted on a light pole whose image radius serves as a geofence; smartphone GPS; 3G to relay local information from the camera sensor to the phone; and Bluetooth technology that can pair a smart phone with a smart cane.

The 360 camera sensors are mounted on light poles distributed throughout the city. The cameras gather low-resolution images between 20 and 60 fps throughout short intervals. In a cloud server, an algorithm analyzes the images and parses them for an approximation of pedestrian and vehicle traffic within the area. The data are exported as a string and published to an API, then also archived.

Smartphone GPS locates the user and also generates a 300-meter “safety bubble” or geofence around the user. This safety bubble activates all camera sensors in its vicinity, allowing for on-demand image processing as opposed to leaving the system running perpetually.

The cameras are connected in a mesh network and can thus be responsive to each other. For example, if an oncoming vehicle is approaching a crosswalk where the visually impaired pedestrian is situated, the mesh network will be able to sense and anticipate oncoming traffic, then broadcast warning message to the pedestrian before they cross the street over a 3G network. The warning message will be delivered in the form of audio on a smartphone. If the pedestrian has a smart cane, it can be paired with a mobile phone through Bluetooth. Whenever the mobile phone receives a warning message, the smart cane will simultaneously vibrate to serve as an ancillary warning.

Smart canes containing an internal compass can also be programmed to vibrate in the general direction of the threat. Because the analyzed data is extracted from the image file, there is no need to save the image file itself. To ensure the privacy of pedestrians on the street, the images are discarded immediately after the software analyzes the image and renders the data. Ultimately, the data collected and archived by the platform can be used to better understand mobility patterns of the visually impaired, identify potentially hazardous areas for visually impaired pedestrians, and contribute to knowledge about the makeup of crowds across the city.

Above: a low-resolution 360 camera is mounted on lighting infrastructure, providing for ubiquitous crowd sensing.
Right: how the technological components interact with each other.
The images are discarded immediately after the software analyzes the image and renders the data.
Lily Bui

Lily Bui is a masters student in MIT’s Comparative Media Studies program. Her research focuses on the use and representation of sensor data in urban contexts. She is also a research assistant at ArchiMedia, a writing and rhetoric lab that explores various aspects of science communications. Previously, she worked as a STEM Story Project Associate at the Public Radio Exchange (PRX) and the Executive Editor at SciStarter, PLOS CitizenSci, and Discover Magazine’s Citizen Science Salon. In past lives, she helped produce the radio show Re:sound for the Third Coast International Audio Festival out of WBEZ Chicago; worked on Capitol Hill in Washington, D.C.; served in AmeriCorps in Montgomery County, Maryland; worked for a New York Times bestselling ghostwriter; and performed as a touring musician.
Guiding Light

by Maxwell Jarosz
Guiding Light aims to take on one major issue in Amsterdam, overcrowding. Amsterdam is a very popular tourist destination, so much so, that it is becoming a major problem. With over 15 million tourists in 2014, Amsterdam-Centrum, Amsterdam’s small city center gets so congested that people can barely move in the street. This makes it tough for tourists to get around, but also for the people that live there. For the citizens in Amsterdam, even small errands can wind up taking large portions of their day because of the crowds.

For the tourists, the crowds and lines make them miss some of the attractions they are coming to see. The massive amounts of tourists have led to a feeling of Disneyfication of the historic center. This has led to many of the citizens moving out of the city center and moving into other parts of the city.

The UNESCO mark on all of the buildings has led to a false sense of the “historic” Amsterdam that is mostly occupied by tourists, similar to an amusement park, Disney-Land. Currently, most of the center is occupied by residents staying from airBnB with almost 11,000 rooms listed.

Guiding Light aims to use the redevelopment of the urban street lighting grid to collect data on urban flow. It will record data on the amount of people and direction of movement, with the data collected being used to alleviate the crowds. This will decongest the historic center to alleviate the Disneyfication of the city.
Amsterdam Population vs Tourists/Year (Millions)

Amsterdam Population vs Tourists/Year (Millions)

Amsterdam Tourists compared to Disney World Tourists (Million per year)
PERSONAL INTERACTIONS

Guiding Light interacts with people on two vastly different scales. The first scale is through the smartphone. This interaction comes through an API ran through Google Maps. This creates a personal interaction between a person, their smartphone, and their environment at the same time. Users can see images of certain areas to check in real time the crowd levels to determine if they should go, or if there is a line, without having to physically be there.

The API also aims to increase efficiency for people on a day to day basis. The citizens can now interact with their phone to compare places they need to go to how the crowds are. In one sense this can be helpful to reroute or determine the amount of time to run errand, in another they can use this to find alternate locations as well to help avoid getting stuck in the crowds. During the night when they want to find a more social and lively setting they can use it in the reverse to find areas that are very active and select a spot they are interested in. Tourists can interact with their phone to maximize their time in Amsterdam by entering their desired locations and getting comparisons to crowd levels and help organize their plans based on those levels. For example, if a person was walking to the Rijksmuseum and Anne Frank museum, the app could warn of lines forming at the Anne Frank museum so to go there first, and then walk to the Rijksmuseum second.

The second way is through the lightpost. Early in the night the lights shine vertically into an acrylic tube which diffuses the light producing a more intimate and less harsh light. The diffuse nature and glowing tube create a more intimate relationship at body height to a person than streets lights that just shine directly down.

Later in the night, the secondary lighting is activated which creates a more traditional light that engages the need for constant light between two posts. These lights are angled to illuminate the periphery of people walking.

The slenderness of the redesigned lightpost, with a large acrylic portion allows it to become less of a sore thumb in the scene, and allow walkers to enjoy more of the scenery of the city without large posts in the way.
Lighting through acrylic tube
Perimeter Lighting
This project interacts with the urban environment in multiple ways. The first is by the physical space of the city. Redeveloping the urban lighting system changes the way the city is light and thus changes the way it is experienced. More intimate lighting engages the people moving through it, while smart controls over the LED lights allow an increased efficiency for the city. Controlling colors through LED’s becomes increasingly easy and can then engage large scale activities happening throughout the city, such as turning the lights orange to represent national pride on King’s Day or to celebrate the national soccer team.

The results of the system also effect the urban interactions by reducing the congestion of the city, creating a more relaxed environment where people can enjoy their day without suffering from the inherited problems of Disneyfication, while still allowing the city to profit of the vast tourist market.

There is also the unseen interactions. The camera is interacting with the people to collect data. The data collected from this system is also useful for urban planning. By giving the city accurate data on both where and how people are moving throughout its city, Amsterdam can be the first city to truly understand and analyze its own urban flow.

This information can be useful for bringing citizens back into the centrum by showing specific streets that see less tourist traffic by comparing normal flows to extreme summer flows. It can also be used to plan new transportation developments, such as knowing which streets should be pedestrian, which need more bike lanes, or wider streets. This data can also be compared to local economic factors such as new openings, or types of places open near or away from crowds to see where the people are going, where they are spending, and how the city is growing and changing based off the urban flow.
Gradient of Brightness Guiding Path

Light Posts Respond to Individuals in the Crowd
TECHNOLOGY DESCRIPTION

Reflective Cone
Sealed Argon Filled Container
Camera
Processor
Wifi/4G
3mm LED Strip
Angled Perimeter Lighting

1/4” Acrylic Tube
Electric Cables
Extruded Steel Tube Frame
Bolt System for Easy Removal/Upgrade
Electric Connection
City Power Grid
CLOUD
Information Systems to Cross Ref
- Paths
- Destinations
- Landmarks
- Previous Urban Volumes
The technology for this project has been developed in two parts. The first part is the redesigned street lighting infrastructure, the second an API developed for Google maps. The infrastructure for the street lighting has been designed to be a sleek and skinny as possible, reaching a maximum radius of only 4”. It is made up of an extruded aluminum frame, with a 1/4” thick frosted acrylic tube that allows the cables from the ground to run all the way up to the electronics on the top. The frame is developed to be easily replaceable as the system is upgraded in the future. The acrylic tube allows diffuse lighting conditions to create a more intimate experience with citizens, while perimeter LED lighting exists to create a wide-enough range of light.

At the top there is a camera that takes images off a reflecting cone. The image is then sent to the cloud where it is unrolled and then assigned x, y, z values to targets in range, dumps the image. The information is transmitted through a 4G signal and processed with the entire system to create an imaged based urban flow analysis. While using a panoramic picture and unwrapping it does take more processing, this system is developed under the premise that processing power continually becomes cheaper and smaller, and the amount of information that can be collected in one panoramic is of more use. It is also presumed that this is the first part of a system that can use the same images to relay other types of data such as being used for crime, urban traffic, and any other future uses.

The urban flow data is then used by the API to determine the best route avoiding the massive tourist congestion, to find the most active areas at night time, or show areas of recent crime. To do this it compares the destination or route style of your choice, and then cross references with volumes of people, GPS data, optimum paths, landmarks, and related destinations. This allows users to create very specific ways of filtering the city based on their preferences while solving one of the major issues in the crowd.
Maxwell Jarosz

Max is currently a graduate student in the Architecture Department at MIT. His current interests are applying new technologies to architecture in material explorations.

A recent project he completed was a translucent concrete wall, embedded with an LED matrix to engage both the interior and exterior in new programmable ways.

He has also done work on applying sensors to architecture to perform a feedback of computational analysis in real time.
Hugging Light
by Myung Duk Chung
PROJECT DESCRIPTION

When sun rises, its light can touch people in many ways and bring forth a state of euphoria. What if city street lamps could also prompt the same euphoric state in unexpected ways? This project engages existing innovative technology and urban infrastructure. It is possible to reimagine using the ubiquitous structure of street lamps in Amsterdam as platforms to address global warming, to communicate information about environmental conditions to Amsterdam citizens.

Invoking human sensitivity with digital technology is one of goals of this project. We are living in a time of rapid and revolutionary change in the world. However, it is important to remind people about interacting with our “analogue” senses. Therefore, the ‘hugging light’ is designed to combine our sense of touch with how we perceive the city lighting system.

Encounters with the unexpected makes life joyful.

The project’s initial idea was inspired by a Korean movie, the classic (1998) which shows the interaction between the digital with human sensibility. In the movie, the male actor turns street lamps on and off in order to attract the woman whom he loves. Light and electricity act as a way to call attention, to reach a certain mode of affect. Urban infrastructures might be used as a mechanism to express oneself. In this particular case, a street lamp becomes a medium for people’s emotions.

The classic, Korean Movie (1998)
Innovative Technology

A previous project from MIT Senseable City Lab, Global Warming, uses technology to interact with our human senses. In this project, sensors perceive the position of people nearby and project a warm light in their specific direction. This is the same concept for the technology used in the ‘hugging light.’

Existing Infrastructure

Street lamps are distributed throughout cities, which can be nodes for technology. There are electrical and steel structures to support different technologies that could be embedded in them.

Interaction

Light and heat bring people together and provide a place for them to socialize and play with each other. In this sense, the streets are no longer street, but playgrounds.
Ten infrared lights are installed vertically in frame, and they are arrayed 360 degrees around the frame.

Parabolic mirrors reflect infrared light and concentrate it to the people’s position. This is not a moving structure but a fixed system. The sensor detects people’s position and distance.
**TECHNOLOGY DESCRIPTION**

**Sequence of Movement # 1**

When a person approaches the system, the sensors detect the distance and angle at which the person is approaching.

**Sequence of Movement # 2**

Then it makes the lights turn on and off according to the person’s movement.

**Sequence of Movement # 3**

This is not a movable structure but a whole fixed system.

1. Existing Structure
2. Sensors
3. Reflector
4. Local Warming Light
5. Glazing
The sensors also detect the distance between the light post and people and controls density of beam. For example, in the case of d1, the beam has low intensity and of d2, the beam has higher intensity than d1. As a user interface, people’s specific behaviors, such as raising hands, deliver signal to the sensor and can increase the density of light. Now, people can play with streetlights. Their interesting gestures generate diverse light with different density, which decorates urban scene.

‘Hugging light’ becomes another way to make Amsterdam an even more beautiful and ornamental city.
1. Thermometer
2. Thermal Camera
3. IR Depth Sensors
4. Main Board
5. Light Connection
6. Infrared Lights
Eventually, this project can also make people more aware of the environment in public spaces. This design is proposed for periods of seasonal change between January and April as well as September and December.

The City of Amsterdam can also develop this system as a data collection tool for urban planning. The lights can be assigned to popular spots in the city and analyze the density of people and flow of tourists.
Hugging light will provide space to gather in cold weather, and their presence might invite more interaction with the cityscape. This analogue reaction with technology will stimulate new activity in Amsterdam.

Those who walk slowly can still far. The hurry is seldom worth it.
Sterrennacht (‘Starry Night’)  

by Charles Steelman
Sterrennacht ('Starry Night') aims to bridge the evolutionary disconnect between man’s natural and virtual selves by utilizing technology to bring people back in touch with nature. Great gains have been afforded to the human race, in terms of productivity, public safety and the ability to live in a “city that never sleeps”, through Thomas Edison’s realization of the incandescent light bulb in 1879, but these gains have been achieved at the expense of the night sky. Sterrennacht’s objective is to resolve a major unaddressed concern with our existing public lighting systems – light pollution and its ill effects.

Many newer public lighting systems pair sensors with efficient LED luminaires to create dynamic lighting systems, but the goal of these systems has focused primarily on energy efficiency. Meanwhile, the issue of pervasive light pollution remains unresolved and, in fact, continues to grow unchecked at a global rate of 6% per year. Such strong growth comes from the almost universally accepted notion that more light means greater visibility and increased public safety. As a result, our cities have become flooded with bright spotlights.

With 99% of the European Union affected by this issue and 93% of all outdoor lighting consisting of public lighting, the project has the possibility of making a meaningful impact. Further, the City of Amsterdam is a center for innovation in lighting and is an ideal candidate to lead the way in addressing this global issue.

Light pollution is not only inefficient and costly to our local governments but also has serious implications for human circadian rhythms and metabolic rates, having been linked to sleep disorders, cardiovascular disease, obesity, and, quite possibly, cancer. Light pollution’s effects extend into the animal realm and are known to disrupt the migration and reproduction habits of countless species. There is a spiritual side to this issue as well – humans have lost their connection to the stars and the infinite bounds of the universe that they represent.

Sterrennacht is an intelligent public lighting system designed to minimize the effects of light pollution in the City of Amsterdam. By sensing the luminance (light intensity) and chroma (color) of its surroundings, the system will effectively create a real-time light map of the city. Its diffuse, full-spectrum LED luminaires will be programmed to automatically counteract the four major causes of light pollution: skyglow (brightness of the night sky over an urban area), light trespass (light falling where it is not intended or needed), glare (harsh, bright light which reduces visibility) and clutter (unnecessary over lighting). Further, the system’s full-spectrum capability will adjust its color output according to the time of day and surrounding natural and artificial light sources to both optimize visibility and minimize biological disruption caused by improper spectral luminance.

The project will initially be installed in Noord Amsterdam, as it represents the only viable expansion area of the city but is both physically, by the IJ River, and psychologically, through negative historic association, disconnected from the historic center. Sterrennacht will help improve the image of Noord to Amsterdammers and visitors alike, thus helping to achieve a major planning initiative of the city.

Overall, the project will provide increased visibility and a sense of wellbeing, while reducing the adverse health effects of light pollution. The system will respond to the many unique features of Amsterdam and will continually adjust under changing conditions. Unique lighting strategies will illuminate zones within the city in different ways and the sensor system will provide rich, real-time data on light levels and activity throughout the city. The project’s success, however, will be measured in the increased number of stars visible from within the city. Most importantly, such a lighting system will reconnect the city with the universe so that Amsterdam will once again become the city of Van Gogh’s brushstrokes.
Cover: Vincent Van Gogh’s ‘The Starry Night’ as a backdrop to Amsterdam’s famous canal houses.

Above: Night sky above a city showing a spectrum of light pollution levels from typical
A citizen of, or visitor to, Noord Amsterdam will have a completely new appreciation for and relationship with the city once the system is installed. While Sterrennacht is designed to operate at the periphery of our attention, the area will be noticeably more even and pleasantly lit than before. While subtle, the color spectrum changes of the lighting system will indicate activity zones within the city, with more crowded and bustling locations being lit in brighter and more exciting hues and less dense and quieter areas being lit in dimmer and more calming colors. Further, while people may not recognize its source, they will experience more restful sleep and overall wellbeing as the biological effects of light pollution are minimized. Most obviously, the stars will become more visible in Amsterdam and especially in residential and park areas where canyons of sky visibility will be created. A person’s interaction with Sterrennacht will extend far beyond the lighting system itself – it is designed to reconnect the entire city with the night sky and the sense of wonder that it can inspire.

Stars will become more visible in Amsterdam.
Sun sets, lights slowly turn on to maintain minimum light level, as detected by sensors.

Light level increases as natural light decreases. Spectrum shifts to "relaxed" (medium intensity) as people leave work and eat dinner.

Sensors recognize slow-moving pedestrian activity and respond by providing dim, diffuse light.

Spectrum shifts to "excited" (high intensity) as people meet up for drinks and partying.

Sensors recognize fast-moving cycling activity and respond by providing brighter light.

Sensors recognize tram or car activity, which emit additional light, and respond accordingly to avoid overlighting.

Spectrum shifts to "serene" (low intensity) as people go to sleep.

Sensors recognize indoor lights going off and respond by dimming lights to minimum light level.

System maintains minimum light level, but is always ready to respond to changing conditions.
Sterrennacht will be initially installed in Noord Amsterdam between the ferry to Central Station and the Eye Film Institute. The site represents one of the most cutting-edge locations in the city, with A-Lab (a media and technology co-working space and incubator) and the soon to open Twenty4 (a music themed mixed-use hotel, club, studio and office tower) nearby. This location was chosen to help bolster the first impression of and connotation with Noord to Amsterdammers. Further, given its low density and proximity to the water, which serves to buffer the site from the bright lights of central Amsterdam, the site serves as a manageable location on which to prototype and test the system.

At an urban scale, a network of wireless photometers and cameras will be installed into the existing lighting infrastructure in order to measure, in real time, light intensity and color composition throughout the city. The light map that will result allows the categorization of different zones in the city, each with its own taxonomy of use and lighting strategy. Residential areas will be lit differently than commercial, retail or park uses. Such patterns of light will then be paired with astrological and weather data to further refine optimal lighting scenarios. The light map will provide real-time data on light usage and activity throughout the city. Further, the light map will assist the city in intelligently placing its luminaires so as to optimize lighting conditions throughout the city. The project will install diffuse luminaires which do not emit light upwards so as to provide uniform luminance at ground level. Gone are the days of patchy light, dark corners, and spot lighting, a major source of glare, sky glow, and uneven light. Such intelligent placement of lighting will help ensure that light is only provided where, when and at such a level and spectrum that is needed. The natural movements of the city will dynamically adjust the output of the lighting

Light map will provide real-time data on light usage and activity throughout the city.
Left: proposed installation location
(Noord Amsterdam).

Right (above): illustration of sensor network
with wide-angle cameras (red) and color/light
photometers (blue).

Right (below): light map showing real-time
light levels.

System (for instance the interior
lights of a tram will reduce the overall
lighting needs of its surroundings) so
that an optimal lighting program can
be continually output at certain hours
of the day and night.
Sterrennacht will be the first dynamic public lighting system designed around the control of light in urban areas. It will do so by first creating a real-time light map of the City of Amsterdam. This light map will allow the system to effectively see where light is coming from and going to. The system will also be able to recognize objects and surfaces that scatter and reflect light and respond accordingly. Further, the sensor network is capable of distinguishing between natural and artificial light sources as well as static and moving objects. Such objects will then be categorized and uniquely responded to such that the lighting needs of a pedestrian, cyclist, automobile and tram can be provided by a single lighting system. The system’s on-board digital image processor will store optimal lighting methods and compare them with and respond to existing conditions. Further, the system’s data will be aggregated on the cloud to allow the system to self-learn over time.

Diffuse light will increase visibility and sense of safety while reducing overall light levels.

The tethered sensor network will be connected to and control a series of diffuse, full-spectrum RGB LED luminaires. The specified luminaires are designed to emit 0% luminous flux wasted upward (above 90 degrees), which will drastically reduce skyglow and light trespass. These luminaires will be intelligently spaced so as to be able to provide even light levels, thus counteracting the glare and clutter of existing spotlighting. Importantly, this diffuse light will increase visibility and sense of safety while reducing overall light levels.
light levels.

The sensor system required for Sterrennacht is relatively simple and inexpensive. It utilizes two types of sensors— a simple color and light photometer sensor and a slightly more complex camera sensor— tethered together via Bluetooth 4.0. The camera sensor is also linked both directly to the luminaires themselves and to the cloud, over existing 3G/4G wireless networks, such that the lights can be controlled locally or remotely. The photometers constantly measure light intensity while the wide-angle cameras measure color composition. Finally, the actuation system consists of programmable, full-spectrum RGB LEDs.
“Let him look at the stars. The rays that come from those heavenly worlds, will separate between him and what he touches. One might think the atmosphere was made transparent with this design, to give man, in the heavenly bodies, the perpetual presence of the sublime. Seen in the streets of cities, how great they are! If the stars should appear one night in a thousand years, how would men believe and adore, and preserve for many generations the remembrance of the city of God which had been shown! But every night come out these envoys of beauty, and light the universe with their admonishing smile.” – Ralph Waldo Emerson, “Nature”
Charles Alexius Steelman

Charles is a dual degree student with the Center for Real Estate (MSRED) and Department of Urban Studies and Planning (MCP) at MIT. He is particularly interested in innovation in the built environment, especially as it relates to technology and sustainability. At MIT, Charles has focused particular attention on real estate finance and contract negotiation. However, he is most passionate about the intersection of design, especially architecture and urban planning, and finance. He plans to be a private, large-scale, mixed-use developer in major metropolitan areas throughout the world. Charles holds a B.A. in Philosophy and Religion from NYU and grew up in Washington, DC. His personal mission statement is to “Build a Better Present.”
A5

Share the Shine

by Wenling Li
Street lighting in Amsterdam’s central canal is already an image of perfection, according to a well-known lighting designer we visited in Amsterdam. But the canal seems dark and neglected at night.

How might we use the lighting system in the city to draw tourists’ attention to other interesting areas outside the central canal area? How can we provide a slight and dynamic lighting effect and add to the charm of canal at night?

**Design Solution**

I propose a water bicycle service system that links the canal network on the inner part of the city to the outer part of the canal network. Along with this, I propose a canal mist projection system that synchronizes with other technologies. In this case, I have proposed a design for how the system would work with water bicycles, a mechanism that allows people to propel themselves on top of water on a bicycle.

In this system, the light nodes function as a camera and projector. They take pictures of the area around them randomly throughout the day and project the image onto a nearby mist screen when a water bicycle passes by. This can be a feature that attracts tourists to the waterfront, either to participate or to speculate, and can promote this particular part of the neighborhood.

Other sensors can be mounted on water bicycles to collect more environmental information about water and air quality. The better the environmental quality, the more intense and larger the generated mist will appear.

Data about distribution of water bicycles throughout the canal area, while the bicycles are in use, will be sent to a data cloud and will be represented on a public platform.

This will help connect different parts of the city to itself through the canal system as well as promote different neighborhoods.
You rent a water bicycle at one of the chain stores scattered in the city. As you bike along a certain route in the canal, your bike begins to sense the water and air quality along the routes. As you are approaching a floating ‘mist & projection’ lighting setup in front of you, it will start to emit mist and project images onto the mist.

The intensity and area of each mist screen varies according to the environmental data in the past 24 hours: the better the water and air quality, the more intense and bigger the radius of the mist screen will be, and the clearer the projection is. The projected images are from three data sets: the first is a set of random images taken from the projecting light pole; the second is a set of images uploaded by tourists in the same neighborhood; the third is a set of images uploaded by residents or shop owners in the same neighborhood. All these three datasets (environmental quality, photographic impression, and projection effects) will be integrated onto a data cloud, shown and updated on a public platform.

One type of interaction with the system is to ‘rate’ the image in the mist projection. The system will receive your rating. After you pass it, the image will gradually fade into a color based on your rating and then disappear.

The color of the fading projection will range from orange to blue according to the rating of a passing water bicycle: ‘very good’ to ‘very bad’.

At a personal scale, your presence will trigger the ‘mist & projection’ lighting sets one by one as you pass through them, and the system makes you feel as if you are always accompanied on your water bike journey.

At the urban scale, it can function as a public monitoring system, promoting and feedback system.
5. Hi, I'm water testing. Canal views from here is tense!
Hi, what are you up to?

6. Yeah, color indicates the water quality here.
The warmer the color, the bigger the warning.
They are real lights accompanying me.
The safety is beautiful, isn't it?
How about the lights?

7. It's changing color.
Wait, they fade out gradually as I pass.
The night is part of its beauty.
Cool, wait, did you turn off the light?

8. Definitely!
If you want to join me, go and check at www.sharetoshine.com.
On a web portal for the system, there is also a real time map of the water quality and distribution of water bikes in use.

Water pollution map

Distribution of water bikes
Water bikes might be supplied by existing companies that produce them, e.g. Schiller bike company. Additional technologies like GPS locator and water quality sensors can be added to the bicycles to collect data.
When a water bike approaches a mist light, the bike’s GPS data from the data cloud will actuate the turning on of the LED light and mist emission. The color of the light is decided by the quality of the water at its vicinity.

The light nodes sit on the water surface while anchored on the riverbed with the help of a rubber tire to keep it buoyant.

Actuator: Mist light
Image at lower right hand corner.
Courtesy of http://www.thehouseofhydro.com/
Wenling Li

Wenling is a candidate of Master in Landscape Architecture, Harvard GSD. She received a Bachelor of Architecture from Tsinghua University, Beijing.

She has an interest at the intersection of urban atmosphere and perception of urban environment.
FlyLight augments existing lighting infrastructure with more flexibility and personalized experience.
The properties and network of street lamps create good platforms for docking stations because:
(1) Streetlamp can provide power supply for charging
(2) Height of streetlamp is favorable for taking-off and landing
(3) The Network of streetlamps allows proximity between docking stations and users, thus enables high-speed arrival of FlyLight.

FlyLight docks on top of a street lamp when it is not being used.
PERSONAL INTERACTIONS

A. CALLING A FLYLIGHT

1. Imagine you are walking or riding a bike in a park midnight. It is very dark and quiet, and you feel a little bit unsafe. Now you can open the FlyLight app and push the “CALL FlyLight” button. Your GPS location is sent to the server and the system finds the nearest FlyLight. Afterwards you receive a notification from the app saying a FlyLight is on its way.

2. A FlyLight from the closest docking station will take off. It will constantly update its GPS information with the server and the server will guide it towards your location.

3. The FlyLight will arrive within minutes. Once the FlyLight reaches your location, it will turn on its high-powered white LED light to illuminate the area ahead of you. While the FlyLight is following you, it will maintain an altitude of 4.5 meters above your head.

One FlyLight for Multiple People
If you and your friends are walking together and afterwards split into different directions, FlyLight will follow the person who made the call (i.e. you).
4.) Whenever the FlyLight passes through the range of another docking station, it will check its battery level and the distance to destination. If the battery level is low, it will notify the server and the server will activate the take-off of FlyLight from this docking station, which will come and replace the existing one. The old one will then fly back to its docking station for charging. This swapping mechanism therefore allows continuous illumination to the user without being limited by the battery life.

If you are waiting/still for a long time OR Your path doesn’t pass through the range of other docking stations In the above scenarios, when the battery level of FlyLight is low, it will notify the server and request replacement. The server will then find the closest docking station to the user and activate the take-off of the corresponding FlyLight.

When you exit the park and don’t need the FlyLight anymore, you can call it off by pushing the “OFF FlyLight” button in the app. The FlyLight will then return to its docking station and be prepared for its next call.
SECONDARY SAFETY FUNCTIONS

FlyLight also includes a personal safety function. Each FlyLight is equipped with a directional microphone, a camera, and a speaker. When you encounter an emergency situation, for example a robbery, while a FlyLight is following you, you can yell “HELP!” loudly, which will be detected by its directional microphone and will trigger automated response behaviors. FlyLight will send a notification to the central emergency system of Amsterdam (i.e. 112), and at the same time start video and audio recording using its camera and microphone for evidence. In this scenario, the LED strips around the propellors and the high-powered LED light emit flashing red and blue light, and the speaker emits high frequency sound to signal attention. The FlyLight will also move in erratic pattern to avoid attacks or tampering with it.

When an emergency is detected, Flylight will emit flashing red and blue light to signal attention, and move in erratic pattern to avoid
URBAN INTERACTIONS

Westerpark consists of a vast space with lots of green. It features a youthful and culturally rich atmosphere – with an art-house cinema, several cafes, a number of starting-up designers’ offices and independent shops. Despite being an area filled with creative industries and having quite a few night clubs, most of the areas of the park remain dark and quiet at night when there are no large-scale public events happening.

The FlyLight system is designed to create a better experience for people in the park at night. Whether they are strolling, cycling, reading or chatting with friends, the lights move with them and create unique enjoyable experience. On top of this, the system not only provides personal illumination but also, in contrast to traditional street lamp, gives users a sense of companionship and safety when they are walking alone. Moreover, as the location of Westerpark is close to the city center, the FlyLight system may help to activate the park during nighttime and attract more tourists towards this unique cultural spot of the city.

As the use of high-density LiPo batteries allows a FlyLight travelling in average human walking speed to have a total flying time of 15 minutes. To accommodate all uses, there would be a docking station in every 312.5 meters of a walking path. Therefore, there would be a total of 64 docking stations in the park.
At the same time, through the interactions between the mobile app and the users, various types of data can be collected, which would be useful in three different days:

**Understanding Demand for Additional Public Lighting**

When a FlyLight is called on or off via the app, the GPS locations of the user and the timestamps are being saved to the server. By collecting such data, usage of the system in different locations, time of the day, and seasons can be analyzed. It therefore enables a better understanding of the demand for additional public lighting in specific areas. If there is high demand at one spot, there may be considerations about creating more docking stations. When the demand is high enough, there can also be the possibilities of building more street lamps.

**Improving Walking & Biking Paths**

Apart from these, the system also enables the collection of data about the time people spend in the area, the forms of navigation (walking/biking) most used, and the paths people take at night. Such data would be useful in improving walking and biking paths in the area.

**Collecting Evidence & Creating Crime Map**

The directional microphone on the FlyLight system allows detection of emergency situations, and at the same time the camera together with the microphone enable automatic collection of evidences.

Furthermore, the GPS location and the timestamp can help to identify hotspots and peak hours for crime.
The FlyLight system consists of three technology components: The FlyLight Quadcopter, The Docking Station, and The Cloud-Based Dispatch System.

### a. FlyLight Quadcopter

The FlyLight is a quadcopter equipped with a high-powered LED panel that can emit white, red and blue lights. It will only be switched ON when it is following the user. For the rest of the time (e.g. take-off, landing, traveling between docking station and the user), the panel will be OFF. The LED strip is used to make visible the quadcopter to people and animals while the LED panel is off.

The directional microphone is always pointing towards the user and can pick up rapid increase in sound volumes such as yelling, which enables detection of emergency situations.

During emergency situations, the speaker would emit high-frequency sound to signal attention. The camera and microphone would also be used for evidence purposes. The video and audio files are stored both in the flash memory of the quadcopter and in the server.

The GPS is used to identify the location of the FlyLight, while the 4G connection is used to communicate with the server.

The landing process of the quadcopter makes use of the camera to detect optical markers on the docking station for positional alignment.
b. Docking Station

The docking station for FlyLight is designed to be integrated into existing street lamps in Amsterdam. One of its major components is a conductive surface which would be connected to the FlyLight for charging. It also has an optical marker to assist the alignment of the quadcopter during landing. The top cover can be opened and closed using the iris mechanism to protect the FlyLight from rain and wind.
c. Cloud-Based Dispatch System

The cloud controls the input and output of information both to the user and the FlyLight. It not only coordinates the positions of FlyLight with the user, but it also coordinates the swapping of FlyLights. The system mainly consists of five stages:

1. Requesting a FlyLight

When a FlyLight is called via the app, the GPS location of the user will be sent to the cloud (server) via 3G/4G. The server will then retrieve information from its database and find the closest FlyLight, followed by sending a message via 4G to activate its take-off.

2. Finding the User

Once the FlyLight has taken off, it will constantly update its GPS location with the cloud via 4G. The cloud will then send information back to the FlyLight, guiding it towards the user’s location.

3. Following the User

Once the FlyLight reaches the user, the cloud receives constant GPS location updates from both the user and the FlyLight. It would then give directions to the FlyLight, ensuring it is constantly following the user.

4. Swapping FlyLights

When following the user, every time the FlyLight passes through the range of another docking station, it checks its battery level and also the distance to destination. If the battery level is low, it would send a replacement request to the cloud, and then the cloud would activate the take-off of the FlyLight on the closest docking station, bringing it to replace the one with low battery.

5. Calling off a FlyLight

When the user reaches the destination, he would use the app to call off the FlyLight. The Call-off message is sent from the phone to the cloud, and the cloud would then send a message to the FlyLight, calling it to return to its docking station.
Alan Kwan

Alan Kwan is a digital media artist and researcher who is currently studying in the Art, Culture & Technology program of MIT. He works at the intersection of virtual reality, cinema, and new media.

His projects combine film, video game and emerging technologies such as life-logging and brainwave sensors, and have been shown at exhibitions including Arts Electronica Festival in Austria, ZKM Centre for Art and Media in Germany, and Museum of Contemporary Art (MOCA) Shanghai. In 2014, he received the Hong Kong Arts Development Council Award for Young Artist (Media Art), and the Asian Cultural Council Fellowship to pursue his graduate studies at MIT. In 2015 he was awarded the Schnitzer First Prize at MIT.