TRACK&TRACE: IMPROVING THE CHANCE FOR SERENDIPITOUS ENCOUNTERS IN URBAN PUBLIC SPACE USING A DRAWING BOT

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Graduation Thesis, August 2015
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Abstract Our frequent use of mobile technologies is altering the way we use and experience urban public space, one of its consequences might be a lower quality of experience of urban public space because of a lower chance for serendipitous encounters. In order to improve the chance for serendipitous encounters in urban public space we have designed Track&Trace a cyber physical urban intervention in the form of an interactive drawing bot. The intervention is measured through a video-based place centered behavioral mapping. Additionally Track&Trace provides a tool to assist place centered behavioral mapping.
Early results suggest Track&Trace as an urban intervention is successful as a way to change people's focus of attention and people's direction of movement, but also to lower people's speed of motion and increase people's duration of stay in urban public space. Perhaps this increases the chance for serendipitous encounters, we cannot conclude however it increases social interaction between strangers.

INTRODUCTION

With the advent of mobile technologies our use of the internet has increased steadily. Recent report shows currently 84% of American adults use the internet (Perrin and Duggan 2015). Most of us are connected to it all day everyday no matter where we are, letting the internet become an extra layer of our lives, providing social interaction, social status, commerce, entertainment and more.

Activities such as doing groceries, shopping for clothes, sightseeing, but also conversing with strangers have moved from physical space into cyberspace, ensuring these activities can now be done anywhere. As a consequence there is an increase in use of mobile technologies in urban public space. We walk around staring at our screens to check our e-mails for spam, ask our partner what kind of groceries we have to get, congratulate our friend with his birthday and check the weather for tomorrows planned BBQ. It is a fascinating sight; people focused on their screens barely seeing where they are walking, abruptly deciding to stand still as a probably safer alternative. It is no surprise they have been called 'smartphone zombies'[1]. Disengagement from our direct environment caused by the use of mobile technologies influences not only our own experience, but also other people's experience of urban public space.

Urban public space and serendipitous encounters

"Once, when you wanted to meet someone, you went to places where you could find anyone - the piazza, Main Street, the local pub, or even the mall. Now, by telephoning or emailing ahead to arrange precise times and places, you can end up meeting only those you explicitly choose to meet." – William J. Mitchell (1999)

Through time public spaces have been spaces where people gather. Distinguished by their accessibility and openness they have been spaces where anyone could see and meet anyone. Public spaces provide diversity; it is in public space that you meet others that do not necessarily have the same life-styles: values, opinions, race or ethnicity. Public spaces provide serendipity; compared to private spaces, the ratio unfamiliar people to familiar people is dramatically higher in public space. Private spaces subsequently provide trust and intimacy. (Hampton et al. 2010, p.4) Professor in communication Keith N. Hampton notes, "Public spaces are an important component of the communication system that provides exposure to diverse messages, brings people into contact to discuss their needs and interests, and helps people recognize their commonalities and accept their differences" (Hampton et al. 2015, p.2). Through time public life has depended on public space and its opportunities for serendipity as a way to establish social relationships across sociocultural boundaries (Mitchell 1999, p.79).

[1] Saidi, Nicole 2012 "Are we headed for a smartphone zombie apocalypse?" *CNN* edition.cnn.com/2012/10/03/tech/smartphone-zombie-apocalypse-comments/index.html

Our growing use of the internet and mobile technologies in urban public space suggests the software layer is shifting our focus of attention from our surroundings to our screens. This does not seem to mean we are glued to the computer screens inside our homes and offices: mobile technologies have allowed us to venture outside; we actually spend more time in public space (Hampton et al. 2015, p.2). It also does not mean we are not social: we engage extensively with people kilometers away, friends but also strangers. It also does not necessarily mean we spend most of our time in urban public space looking at screens: we spend time with people with whom we have arranged meetings or go to organized gatherings. But if our focus of attention has shifted from our surroundings to our screens, are we still available for serendipitous encounters?

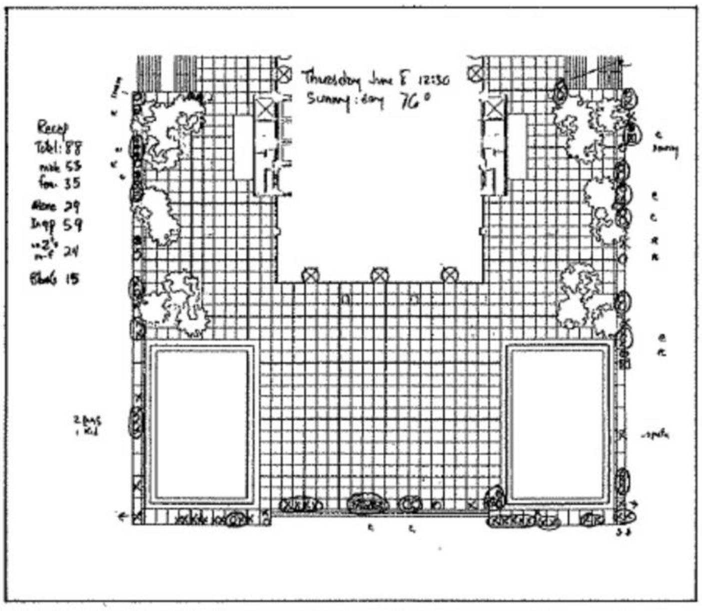
Perhaps serendipitous encounters have moved to the virtual layer, providing new ways to establish social relationships across social, cultural and physical boundaries. In 'Change in the Social Life of Urban Public Space' Hampton notes our social lives have not become less diverse with the advent of mobile technologies.
But if serendipitous encounters are moving to the virtual layer, the amount of serendipitous encounters in urban public space will decline, conceivably leaving our experience of public space focused on private matters and planned experiences. A public space focused on private matters and planned experiences imaginably contributes to a decrease in quality of experience of urban public space.

Inspired by the apparent decline of serendipitous encounters in urban public space, this paper introduces Track&Trace, an experiment to increase the chance for serendipitous encounters. The first part introduces methods for measuring social interaction and serendipitous encounters in urban public space. The second part proposes the design of a cyber physical intervention and interface with the aim to improve the chance for serendipitous encounters, followed by the introduction of Track&Trace, a cyber physical urban intervention in the form of an interactive drawing bot. Finally we conclude with an analysis of its influence.

ANALYZING SOCIAL INTERACTION IN URBAN PUBLIC SPACE
Analyzing social interaction in public space has been of interest to many different research fields, resulting in many different methods of analysis. One of the most conventional methods of analysis is using a place centered behavioral mapping; carefully observing people's behavior and documenting it as objectively as possible (Alexandra et al. 2009).

Many studies on analyzing social interaction in public space make use of place centered behavioral mapping (Hampton et al. 2015; Hampton et al. 2010; Whyte 1980). This can be done manually but nowadays also automatically.
Automatic data collection techniques involve automatic people tracking. The most conventional methods for doing this have been GPS tracking and video analysis through computer vision techniques (Alexandra et al. 2009, p.9). In both cases dedicated software will analyze the input – either GPS coordinates or video tracking coordinates - and extract abstract information that might say something about the interactions taking place between the people being tracked.

In 1969 the urbanist William H. Whyte formed a research group named The Street Life Project with the aim to study pedestrian's behavior in urban public spaces in New York City ("Project for Public Spaces" 2015). For this Whyte, accompanied by a group of research assistants, carried out a series of place centered behavioral mappings. They mounted time-lapse cameras overlooking urban public plazas in New York City and kept notes and sighting maps i.e. to mark places where people would sit down and whether they were alone or not (Fig.1). Albeit manually, Whyte and his team tried to log as much behavioral data as possible, as accurately and as objectively as possible. All findings were collected in a book named "The Social Life of Small Urban Spaces" (Whyte 1980), later releasing an accompanying film (Whyte 1988).
All observations were thoroughly described thereby quantifying as much information as possible, some examples:
A chart of the number of people per 1000 square feet of open space; a chart of the average number of people sitting; the amount of time people sit: "Of the total […] about three quarters was logged by people staying 11 minutes or more…" (Whyte 1980, p.72); the proportion of people in groups and the proportion of women.



This is a typical sighting map. We found that one could map the location of every sitter, whether male (X), female (O), alone, or with others (XO), in about five minutes, little more time than a simple head count would take.

Figure 1. Whyte's sighting map (Whyte 1980, p.23)

The Street Life Project proved to be a one-of-a-kind study. Whyte and his team really took the time to grasp the situation and identify with the people that were studied while at the same time objectifying their findings to gather quantitative results. Finally Whyte also proposes solutions to improve urban public space. On the grounds that these are aimed towards architects, urbanist and policy makers that have to design or decide for urban public space, they come in the form of architectural interventions e.g. the availability, size and height of benches, the width and shape of walkways and the use of sightlines.

Analyzing social interaction in hybrid urban public space

Although urban public spaces have extensively been designed by urban planners and architects aiming to shape our experience of the city, "...[mobile technologies] and the ways in which we use them have perhaps become […] more important than architecture in shaping our experience of urban space" (Shepard 2011, p.25).

We use mobile technologies wherever we go and whatever we do, often keeping our focus on the virtual layer when in urban public space i.e. checking maps for directions and sending messages to friends. One might say our current public space has become a mix of physical space and virtual space. While we are walking through the city and using our smartphone to communicate, we are physically present in physical space but at the same time virtually present in virtual space. Are we in two spaces at the same time?

In 'From Cyber to Hybrid: Mobile Technologies as Interfaces of Hybrid Space' de Souza e Silva notes it doesn't make sense to differentiate between the physical and the virtual; virtual space is not an 'other' space. Subsequently de Souza e Silva defines a new type of space named 'hybrid space': "Hybrid spaces are mobile spaces, created by the constant movement of users who carry portable devices continuously connected to the Internet and to other users" (de Souza e Silva 2006, p.262). The advent of hybrid space has conceivably changed the way we use urban public space, or now hybrid urban public space. The places we visit, the value these have and the contacts we keep are all changing because of mobile technologies (Waal 2014, p.8).

In 'The Social Life of Wireless Urban Spaces' Hampton describes results from a behavioral mapping of public space that is within reach of a free Wi-Fi point. Here Hampton focuses on mobile technologies that connect through Wi-Fi. He finds that the level of social diversity to which users of mobile technologies are exposed is less than that of people that are not. He notes, "…the activities associated with Wi-Fi use reduce the ability of urban public spaces to afford exposure to social diversity for Wi-Fi users, because they are simply less attentive to their surroundings" (Hampton et al. 2010, p.24). This goes along with "…[a] reduced attention to surroundings, in the form of people-watching, a focus on private, head-down activities, and limited response to stimuli from the environment" (Hampton et al. 2010, p.19).

Four years later in ‘Change in the Social Life of Urban Public Space’ Hampton focuses on social isolation. Here he finds "…mobile phone use is associated with reduced public isolation [and] an increased likelihood to linger" (Hampton et al. 2015, p.2). He also notes, “Despite the ubiquity of mobile phones, their rate of use in public is relatively small". In its behavioral mapping Hampton et al. (2015) coded individuals in each area of four characteristics: gender, group size, lingering, and mobile phone use, where lingering is defined as "inhabiting the same area for fifteen seconds or more" (Hampton et al. 2015 p.14-15). For use of the word ‘lingering’ Hampton refers to Whyte noting that public spaces should be designed to “encourage people to linger, as it provides for conversation and chance encounters.” (Hampton et al. 2015, p.5).

Requirements for serendipitous encounters

To use a place centered behavioral mapping to analyze social behavior and specifically serendipitous encounters in urban public space, we set out to find measureable requirements for serendipitous encounters. Hereby we took into account these can be measured unobtrusively, ideally through video analysis. One of the main cues we can take into account when characterizing people’s behavior from video analysis is motion (Calderara and Cucchiara 2012, p.20).

Generally we can say serendipitous encounters are identified by exposure, or our willingness and availability to interact. One measure of exposure is our direction of sight. Looking away is a common and well known method for ignoring other people or communicating we do not want to interact. Subsequently when we do look towards other people, we come across open, accessible and probably willing to interact. In public space this is often found in the form of ‘people watching’, “…the tendency of people to concentrate attention on the activities of strangers” (Hampton et al. 2010, p.18). Clearly when people are watching their smartphones they are not watching people. The more people are staring at smartphones, the less people are available for serendipitous encounters. In order to foster serendipitous encounters we need to start with getting people to ‘look up’ from their smartphones into their surrounding environment. Furthermore proxemics provide a measure for exposure. Proxemics say something about our mutual behavior and the relation we have to each other; usually we keep a longer distance to strangers then to our friends and family (Calderara and Cucchiara 2012, p.22). Proximity “indexes intimacy, [and] is often treated as a signal of availability and openness” (Licoppe 2013, p.123). Subsequently the closer people are to each other, the more open they are to interactions. Finally, motion provides a measure for exposure. Our speed of motion for example says something about our availability to interact; people that are rushing might not be available for interaction simply because they do not have time. People that are moving slowly are usually comfortable and relaxed, making them more prone to engage in serendipitous encounters. Similarly our duration of stay says something about our willingness to interact. The slower we move the longer we stay around – we could also be ‘lingering’.

DESIGNING AN INTERVENTION FOR HYBRID URBAN PUBLIC SPACE

The definition of hybrid space suggests we cannot design or develop for either physical or virtual space: we have to design for both. Subsequently the design of our intervention needs to interface between the physical and the virtual. Mobile technologies too interface between the physical and the virtual. The interfaces they provide however are not always appropriate for use in hybrid urban public space. They mainly provide private interactions, only for one pair of eyes to see, even when the basis of the interactions are very public i.e. posting a tweet on Twitter. For interactions that desire to be more public we require a visible interaction, one that is not privatized by the boundaries of the screen; an alternative, bigger and more accessible representation of a hybrid interface. In ‘Urban computing in the wild’ Salim and Haque refer to these interfaces as ‘cyber physical systems’; systems that “bridge the physical world with the virtual, enabling rich interactions between the two worlds through sensing and actuation” (Salim and Haque 2015, p.34). These are not small mobile technologies but usually bigger gestures incorporating many different types of interactions. Breaking the boundaries of the screen's rigid rectangle “…opens up the possibility of places that engage our senses and attract our attention at multiple levels" (Mitchell 1999, p.38). These interfaces add the possibility to involve more people in a location based interaction instead of individually staring at our smartphone screens.

Considering serendipitous encounters, the presence of a cyber physical system in urban public space not only has the ability to improve the interface between the physical and the virtual, it also produces a visual cue or happening asking for attention. This way the use of a cyber physical system increases the chance that people ‘look up’ – it provides a way to grab their focus of attention and then through the cyber physical system move the focus forward to something or someone else.

The consensus we propose is that because cyber physical systems provide smoother interfaces between the physical and the virtual than mobile technologies in urban public space, they overcome the obstructions imposed by mobile technologies and open up new opportunities for us to interact with people in urban public space. Thus the cyber physical system acts as an interface between the physical, virtual and humans in urban public space.

Naturally many before us have made inspiring works fitting as interfaces between the physical, virtual and people in urban public space. Here we will list some that we consider the most relevant for this context:
'Hand from Above' by Chris O'Shea[2] involves an urban screen apparently showing CCTV footage of its surrounded public space. The footage however plays with pedestrians' perception by playfully manipulating the live video images, seducing many people to stop, stare and interact with the screen. 'Dune' by Studio Roosegaarde[3] is an interactive landscape of light 'fibers' activated by pedestrians' motion and sound; the fibers light up as people are passing by. 'Semi-Senseless Drawing Modules' by So Kanno and yang02[4] consists of drawing modules that are holding pens and moving up and down a wall. The sounds and movements of people passing by influence the drawn end result. More recently LUSTlab in collaboration with The Mobile City created 'Binnen de Lijnen'[5], a physical sidewalk chalk based visualization of spatiotemporal usage of a public square to be colored-in by children themselves. But web based experiment 'Exhausting A Crowd' by Kyle McDonald[6] should also be noted: this online view of a CCTV camera provides the possibility to click and tag anything in view in order to 'exhaust' Piccadilly Circus in London. Kyle was inspired by "the classic 60-page piece of experimental literature from Georges Perec, "An Attempt at Exhausting a Place in Paris"".

We have designed Track&Trace, a cyber physical system that similarly interfaces between the physical, virtual and people in urban public space. We will combine this however with a place based behavioral mapping to see how the intervention actually influences people's focus of attention, mutual proximity, speed of motion and duration of stay. This in order to analyze if the intervention increases the chance for serendipitous encounters. We expect the cyber physical system to lower the speed of motion, lower the mutual proximity and increase the duration of stay.

TRACK&TRACE

Track&Trace is an interactive drawing bot that visualizes spatial relations between people moving through urban public space. The drawing bot responds to people's presence by following them around through space carrying a piece of sidewalk chalk. Aiming for active engagement (Haque, 2015) Track&Trace provokes pedestrians to interact and perform with the space. The goal is to support serendipitous encounters.

Through top-down analysis of pedestrians' movements Track&Trace attempts to interpret invisible tensions between people i.e. based on focus on attention, speed and proxemics. Hereafter the system (or manually the moderator) will select one of the pedestrians to track and trace by following it around with the drawing bot. As soon as the pedestrian is locked, the drawing bot will start to draw. When another pedestrian is close, the drawing bot will attempt to 'notify' the selected pedestrian with the other pedestrian's presence by moving between them. This may be comparable to Facebook's 'People You May Know' function, but then 'People You May See'. For this the slowest and the closest person gets selected, on grounds that this person is theoretically the most exposed/available for serendipitous encounters. Considering focus of attention, the moderator (person in control of the intervention) can manually select pedestrians that are not focused on their surroundings i.e. focused on a screen.

[2] http://www.chrisoshea.org/hand-from-above
[3] https://www.studioroosegaarde.net/project/Dune/
[4] https://vimeo.com/102675809
[5] http://www.creativeapplications.net/processing/lustlab-colouring-in-the-spatial-organization-of-schilderswijk/
[6] https://github.com/kylemcdonald/ExhaustingACrowd

Figure 2. Track&Trace drawing bot on site

Through coupling pedestrians’ actions in virtual space (camera tracking) with their actions in physical space, the borders between the physical and virtual get blurred. The chalk lines leave behind a visualization of virtual tensions; “…flows of information that previously occurred mainly in cyberspace can now be perceived as flowing into and out of physical space…” (de Souza e Silva 2006. p.256). This way Track&Trace functions as a cyber physical system (Salim and Haque 2015) positioning people in hybrid space and providing a cue or happening to let them focus on their surroundings again.

Apart from potentially creating an attractive visualization, the lines created by the drawing bot also aim to create awareness, not only about the presence of others, but also the *temporal* presence of others, the usage of space and the presence of tracking systems such as CCTV cameras, providing new ways of thinking about movement in hybrid urban public space. One result of shifting our focus of attention from our surroundings to our smartphone screens is us pursuing mostly target-based movements (Huldtgren et al. 2014). We move from destination to destination without paying much attention to our surroundings. Awareness about the temporal presence of others and the usage of space might alter pedestrians’ desired direction similar to the phenomena of walking through fresh snow – to go where no one has gone before - potentially revitalizing space that is mainly used as passageway.

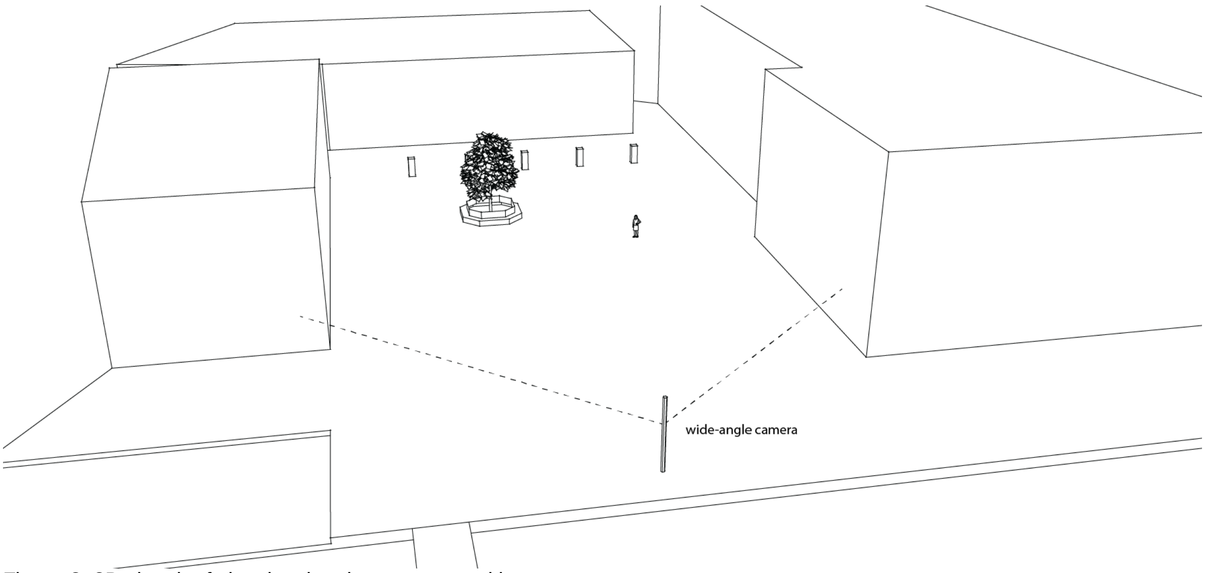


Figure 3. 3D sketch of site showing the camera position

System Description
The site selected for the intervention is a relatively new urban public square on the east side of Amsterdam called 'Oranje Vrijstaatplein'. The square is aimed towards pedestrians; it does not have dedicated car roads nor dedicated bike paths. The square connects a shopping area, café's and the east district city hall. Most traffic travels to and from the city hall. The square is approximately 30m x 50m wide and has one tree with a bench around it (Fig.2&3).

The drawing bot is actuated by an overhead tracking system running a custom creative application made using openFrameworks[7]. The tracking system consist of a laptop computer and a wide-angle camera mounted at approximately two-and-a-half meters height to a flag post at a centered location on the side of the square (Fig.3). Using the Open Source Computer Vision library (OpenCV), pedestrians are tracked via a running background subtraction. The robot is tracked via color tracking.

The system automatically calculates speed, duration and mutual proxemics of all people in view of the camera in real time. Considering its purpose it was too time intensive to develop a system that automatically tracks people's focus of attention (e.g. are they looking at their phone?) so it was decided to provide a way to manually label them. The label status can be set by merely clicking the destined 'blob' in the application. Hence the tool combines the strengths of computer vision with the strengths of human vision. Furthermore this functionality provides a way to manually select the targeted pedestrian – as a way of moderating the intervention.
Subsequently through projective transformations the application calculates estimate real-world coordinates for the people as well as the drawing bot. Concurrently the application runs a steering simulation based on these coordinates. Using the robots real world rotation - received via wireless communication - the system calculates its desired direction and velocity to generate instructions for its operation.

The drawing bot itself is a robot built from an old radio-controlled car. Multiple robots were made, the final robot carries an Arduino[8], a wireless communication module, three ultrasonic sensors, a digital compass and a servo. The servo actuates an arm holding a piece of sidewalk chalk. Attached to the robot is a bright yellow ball to assist color tracking, multiple pedestrians noted it looked like a sort of big yellow antenna (Fig.2). The robot works best on paved terrain and roads, it cannot overcome obstacles such as the curbside.


Figure 4. camera setup


Figure 5. chalk lines made by drawing bot

[7] openFrameworks is an open source C++ toolkit for creative coding www.openframeworks.cc
[8] Arduino is an open-source electronics platform www.arduino.cc

TOOL FOR PLACE CENTERED BEHAVIORAL MAPPING

Additionally a tool is created to assist with place centered behavioral mapping. The tool provides a way to quickly detect objects in view of a camera and keeps track of their size, speed, amount of time spend in view and their proxemics. It is based on the same creative application that runs the drawing bot.

As mentioned above, the tool provides a way to manually label blobs that signify people using mobile technologies. Likewise the tool provides a way to manually label tracked blobs that are undesired such as false positives, so they can then be left out of data analysis. In a way we can say video analysis gets done automatically but with manual human 'help'. The tool automatically translates camera view to plan view (Fig.6) using projective transformations, this provides a quick means of visualizing spatiotemporal walking patterns and density heat maps and for example marking where people are sitting, similar to Whyte's sighting maps.

Of each blob that is tracked the application aggregates its ID, its manually selected focus of attention, average proxemics to all other blobs per frame, velocity per frame, amount of frames/duration blob is in view and the blob size and position. This all gets exported to XML.

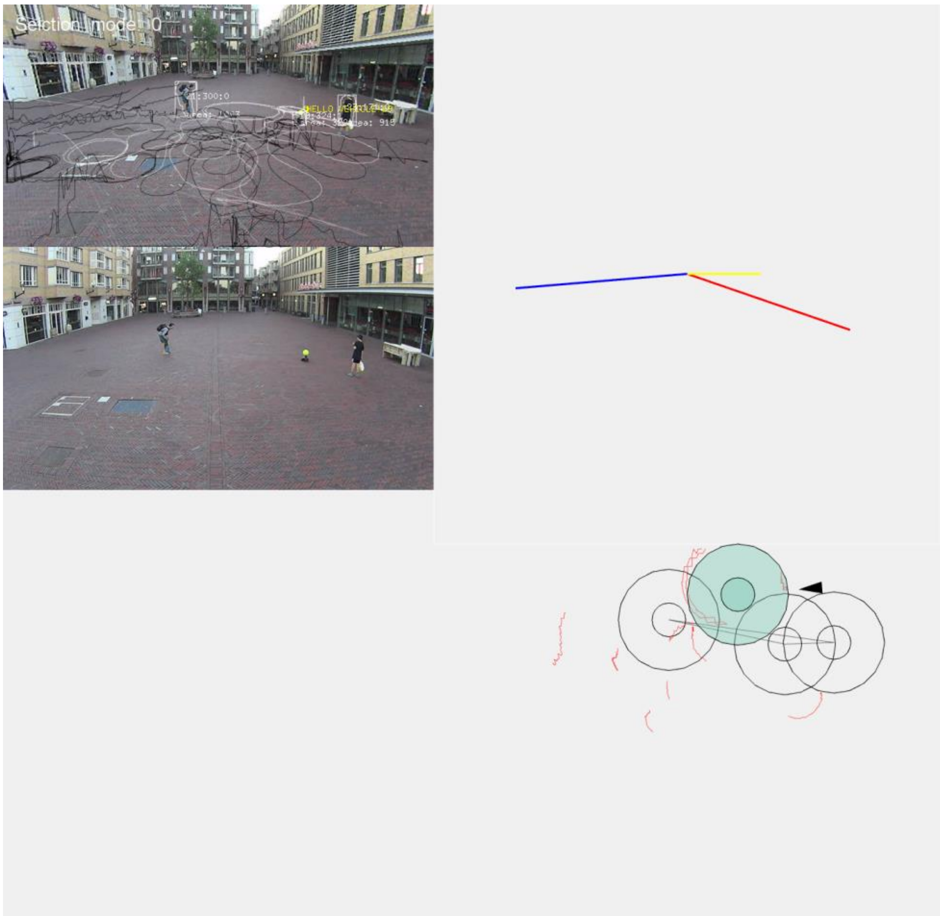


Figure 6. Track&Trace screenshot of software – left: camera view; right: plan view
the drawing bot is represented by a triangle

ANALYZING TRACK&TRACE

Video captures of the square were taken with and without Track&Trace as unobtrusively as possible (Fig.4). A total of ten hours were captured all taking place in august during weekdays between approximately 13:00 and 16:00. Additional manual notes have been taken to document specific human behavior.

During the captures *with* Track&Trace the installation was not running continually as a cause of trial and error. Subsequently it was decided to only pick the parts where Track&Trace was up and running, resulting in a selection of captures with a total duration of 60 minutes. In a later stadium it turned out the custom tool was highly sensitive to light conditions due to the use of background subtraction. As a result it was decided to use the parts were Track&Trace was not up and running of the same days as selection *without* Track&Trace, also a selection of captures with a total duration of 60 minutes. Selected captures were analyzed using the custom tool for place centered behavioral mapping.

Data visualizations were made to assist spatiotemporal analysis. Figure 7 shows a visualization of the square with and without Track&Trace of day1, Figure 8 shows a visualization of day2. White circles (circle size) refer to proxemics, colored circles to blob size, the color itself refers to velocity (the bluer the slower).

Quantitative analysis

During the captures without Track&Trace a manual count took place. All people children and adults, walking or biking were counted; people in cars or on scooters or motorcycles were left out.
Data from 4 hours of watching shows 6.7% of all people visibly used mobile technologies in urban public space (Table.4). From these 127 people using mobile technologies, the ratio male to female is approximately 6:4 and 78% of them were alone (Table.5). Although we did not take notes on age, it was clear that overall mostly people between 20 and 40 years of age were using mobile technologies.

no. people w/ mobile technologies	127
total no. people	1896

Table 4. people using mobile technologies in urban public space

no. people using mobile technologies (from a total of 127)	
75	Male
52	Female
100	Alone
27	In company
117	Walking
10	Biking

Table 5. people using mobile technologies in urban public space

Data from the tool for place centered behavioral mapping includes velocity, proxemics and duration, with and without Track&Trace. Paired t-tests were used to compare with and without Track&Trace on the same day, as mentioned above, to minimize the influence of different lighting conditions. Table 1 shows average, median and standard deviation for the velocity of people over time in meters per second for an n amount of frames on day1 and day2. Table 2 shows average, median and standard deviation for the average proxemics between people over time in centimeters for an n amount of frames on day1 and day2. Table 3 shows average, median and standard deviation for people's duration of stay for an n amount of unique blobs for day1 and day2. Duration of stay was measured in the amount of frames a unique blob was present. In order to be able to compare duration of stay we had to equalize the amount of blobs with and without Track&Trace.

As expected the data shows the speed of motion of blobs tracked with Track&Trace is lower than without Track&Trace. And subsequently the duration of stay is longer with Track&Trace than without Track&Trace. Mutual proxemics however were higher with Track&Trace during day1 and lower during day2.

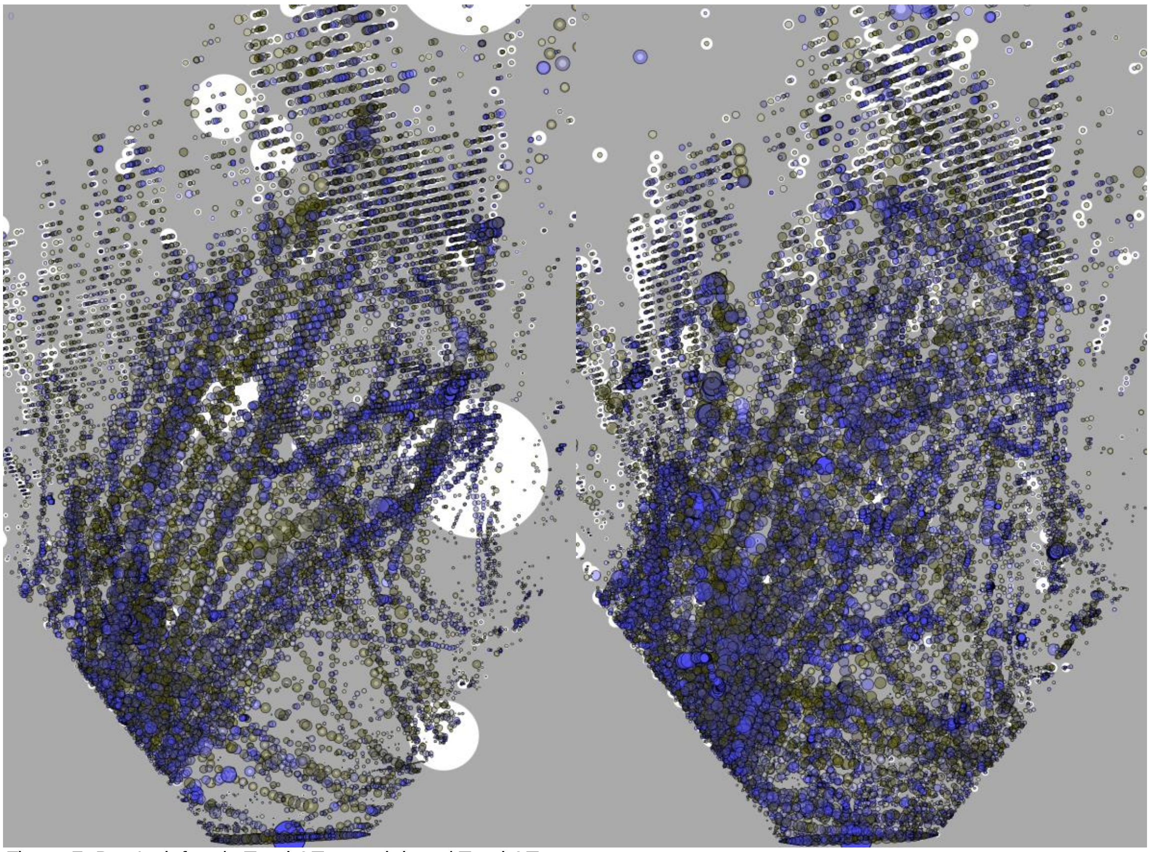


Figure 7. Day1 - left: w/o Track&Trace; right: w/ Track&Trace

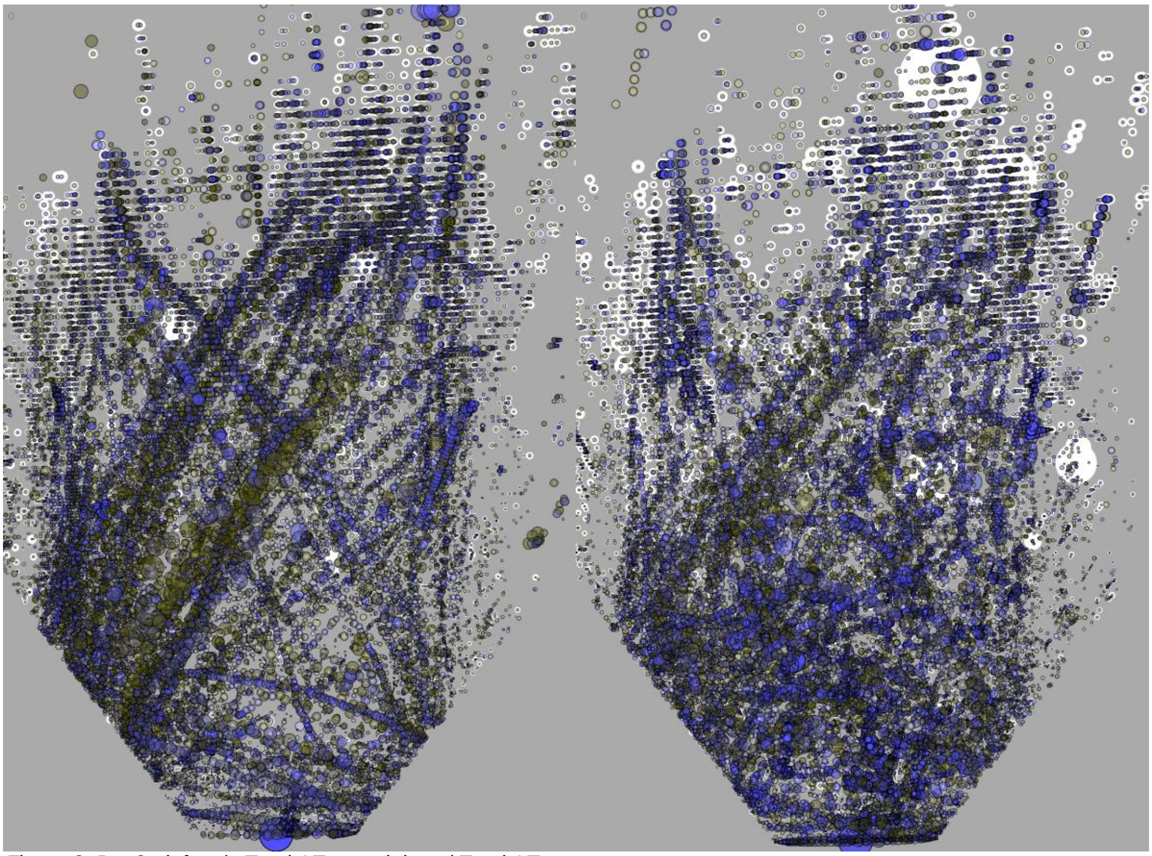


Figure 8. Day2 - left: w/o Track&Trace; right: w/ Track&Trace

Velocity in m/s	Day1: w/o Track&Trace	Day1: w/ Track&Trace	Day2: w/o Track&Trace	Day2: w/ Track&Trace
Average	2.80	2.03	2.66	1.96
Median	1.57	0.87	1.57	0.99
Standard Deviation	4.17	3.48	3.86	3.04

Table 1. velocity over time in meters per second for day1 ($p < 0.001$; $n = 21837$) and day2 ($p < 0.001$; $n = 32387$)

Proxemics in cm	Day1: w/o Track&Trace	Day1: w/ Track&Trace	Day2: w/o Track&Trace	Day2: w/ Track&Trace
Average	123.45	129.48	114.50	91.47
Median	66.04	77.20	67.95	74.56
Standard Deviation	158.54	146.34	141.74	83.14

Table 2. proxemics over time in centimeters for day1 ($p < 0.001$; $n = 21837$) and day2 ($p < 0.001$; $n = 32387$)

Duration in frames	Day1: w/o Track&Trace	Day1: w/ Track&Trace	Day2: w/o Track&Trace	Day2: w/ Track&Trace
Average	177.81	196.73	178.40	280.21
Median	9	7	21	22
Standard Deviation	373.81	440.85	390.64	591.36

Table 3. duration of stay in amount of frames for day1 ($p = 0.45$; $n = 559$) and day2 ($p < 0.001$; $n = 1042$)

Qualitative analysis

Due to long video captures and thorough video analysis the decision was made to not do a formal questionnaire, however many interesting observations were made that I feel need to be discussed.

Without a doubt working on a robot in urban public space increases at least your own chance for serendipitous encounters. Many people approached me – almost all excusing themselves - asking me what I was doing. Some people commented on it being a bomb, some people approached me with the question if this was a 'drone'.
Most people did not notice at first sight the robot was drawing, when they did they immediately pointed it out to their company (if there was company) and usually took some time to look at the bigger picture. In one situation a woman addressed strangers passing by to tell them the robot was drawing, the strangers however – perhaps surprised by the woman's approach - ignored her and the robot and kept walking.
People that were completely focused on their smartphone looked up for maybe three seconds to then continue focusing on their smartphone.

Approaching people by driving up to them got most people's attention. When I was not in sight, generally people looked at the robot first, then around - to see who is involved.
Overall children (opposed to adults) seemed to be most overwhelmed by the bots presence, almost all asking their parents for explanation (that they almost all could not give). Some (ironically) had their parents sitting on the bench using their smartphone - I guess kids don't have a smartphone yet. Most children felt the abrupt desire to run towards or around the robot either obstructing its path or chasing it down. Almost all of them noticed the bot drives backwards when you get too close to its front. They all seemed to attribute lifelike behavior to the drawing bot and almost all children that approached me asked me what the robots name was. One notable situation involved a boy constantly calling the bot 'meneertje' (loosely translated to: little sir), together with a girl that ordered the bot to "stop right now!", "drive backwards!" and "follow me immediately!" (Fig.9). Recent research shows children can be surprisingly abusive against robots (Brscić et al. 2015) - and it is all on video[9].
Another notable situation was the engagement of a surprisingly interested elderly woman with a walker (Fig.10). The woman also attributed lifelike behavior to the drawing bot and proposed to help me testing my tracking algorithm by posing as target. She hypothesized the robot would 'see' her better than other people because of the presence of her walker.

All police officers passed me without at least a glimpse of interest. One officer from 'Handhaving en Toezicht'[10] approached me to ask me what I was doing, as soon as I referred to it as a research project it was not a problem.

[9] 'Robot Tries to Escape from Children's Abuse' on YouTube https://www.youtube.com/watch?v=CuJT9EtdETY
[10] 'Handhaving en Toezicht' is a civil service provided by the city of Amsterdam to actively monitor safety in urban public space

Because the square connects to the east district city hall, some city hall employees approached me with sincere interest in the concepts behind Track&Trace. One lady enthusiastically speculated about letting the bot layout specific routes through the city.


Figure 9. children obstructing the bot's path


Figure 10. elderly woman with walker

DISCUSSION

Data shows the speed of motion of blobs tracked with Track&Trace is lower than without Track&Trace. This might mean the intervention indeed catches people's attention and causes them to move slower. The proxemics however were inconclusive; they were higher during day1 and lower during day2. This means we cannot confirm the intervention causes people to voluntarily or involuntarily move closer to each other. The duration – or amount of frames the blob was present - was influenced by the systems blob tracking algorithms: occasionally different people were tracked with the same blob ID thus registering the same duration. Nevertheless during day2 people spent notably more time on the square with Track&Trace than without. We ended up not using the tool to label the pedestrians' focus of attention because of the high and remote viewpoint and a low video resolution, consequently it was decided to leave this out of the quantitative analysis.

Added data visualizations show the spatiotemporal usage of the square is noticeably different with and without Track&Trace. This is potentially in part due to the robot self, people will have to walk around it instead of going straight, but ostensibly many people also walked up to the robot or passed it very close to quickly check it out.

Undoubtedly the tool for place centered behavioral mapping could have been more exact. The applications' function to manually add labels proved useful as a way to minimize false positives. It also proved useful as a way to moderate a live installation. We could not use it however to label people using mobile technologies, this could be done in a future iteration. In order to have a unique blob for each person the tool can be supplemented with more exact people tracking algorithms, accordingly people counting could be added to its functionality.

Spending almost two weeks working on a drawing bot outside in urban public space is a great experience, however urban settings are very challenging for experimentation. Experiments have been jeopardized by unpredictable and fluctuating weather and thus light conditions, uncontrolled behavior of pedestrians and limited ability to be unobtrusive. Video captures without Track&Trace were taken as unobtrusively as possible, however a person attaching a camera to a flag post is not a common sight in urban public space. Presence of the camera influenced the way people behaved. "It has been shown that people who know that they are participating in a study tend to adapt their behaviour – consciously or subconsciously – to what they expect to be socially desired behavior" (Alexandra et al. 2009, p.12); the well-known 'observer-effect'. Video captures with Track&Trace ended up being even more direct. Having to identify as researcher and explain the purpose of the intervention certainly influenced the way people behaved.

As a result of a single camera setup there were inconvenient tracking inconsistencies such as people overlapping each other and imperfect projective transformations. Future iterations should consider a stereo camera setup for more precise tracking. In trying to compensate for the people overlapping each other we additionally recorded blob size, assuming a bigger blob size suggests multiple people overlapping each other. However because cars, motorcycles and bicycles also generate bigger blob sizes, blob size was left out of quantitative analysis – it is shown however in the added data visualizations (Fig.7&8).

Due to 'buggy' communication between drawing bot and application, in some Track&Trace experiments the system did not function correctly. Consequently a lot less data was useful for analysis.

The system also did not work well enough to comprehensively test its interaction design. Because of a delay in communication the bot did not respond as quickly as envisioned and the robot was not able to drive straight lines. The latter however added a nice almost creature like behavior that we did not think was a problem. We are assuming most people did not notice any particular behavior to the bot, making it seem random. This randomness might contribute to its creature like appearance, however unfortunately it also means parts of the interventions' underlying concepts could not be communicated. We are assuming the generated on site visuals (chalk markings on the square) were too minimal and too inconsistent to get people to realize what was going on. But this might also reinforce people's experience of serendipity, exploring the behavior of this strange robot creature – making it extra rewarding to finally find out what is going on.

Children, who effectively spend most time interacting with the bot, continuously forced the bot to drive backward. Presumably this interaction was more interesting than it driving forward since it responded quicker and perhaps gave the user a feeling of being in control. Apart from the children, no other people seemed to have made an effort to understand the robots behavior (aside from asking me directly).

Sadly we have to conclude it appears that people that were completely engaged with mobile technologies, were so engaged that even a drawing bot could not get them out of it. Also, apart from children interacting with each other, we did not notice any adults interacting with each other. Nonetheless, the fact that people first looked at the robot and then to their surroundings, has potential. This is the first step towards serendipitous encounters. Unfortunately we were not able to track the focus of attention of each pedestrian thus we cannot say anything about its significance.

CONCLUSION

Track&Trace investigates the possibility to improve the chance for serendipitous encounters on an urban public square on the east side of Amsterdam. A prototype was created and experiments took place in the form of an urban intervention accompanied by a place centered behavioral mapping of its influence.

Early results suggest Track&Trace as an urban intervention is successful as a way to lower people's speed of motion and increase people's duration of stay in urban public space. Additionally it was observed Track&Trace changes people's focus of attention – be it even for a little while – and people's direction of movement. Perhaps these changes increase the chance for serendipitous encounters, unfortunately we cannot prove they lead to social interaction between strangers. We have to conclude the experiment mainly functioned as a proof of concept.

The developed tool for place centered behavioral mapping proved useful for its application, however open for improvements. In the future the tool could be extended and used for more place centered behavioral mappings of cyber physical systems and urban public space.

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