Title: Catching the World's Eyes

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1. INTRODUCTION

Visitors to a city have many ways of leaving voluntary or involuntary electronic trails: prior to their visits tourists generate server log entries when they consult digital maps or travel web sites; during their visit they leave traces on wireless networks whenever they use their mobile phones; and after their visit they may add online reviews and photos. Broadly speaking, we propose two types of footprint: active and passive, also referred in the literature as volunteered and contributed locational information (Harvey, 2013). Passive tracks are left through interaction with infrastructure, such as the mobile phone network, that produces entries in locational logs, while active prints come from the users themselves when they share locational data in photos, messages, and sensor measurements.

The World's Eyes project (Figure 1) investigated the active prints that reveal how people travel and experience the city. Particularly, we used the Application Programming Interface (API) of the photo-sharing platform Flickr to access publically available photos. In February 2009, Flickr broke the hundred million georeferenced photos count (over a total of 3 billion photos in the repository). This represents an unprecedented amount of publicly accessible data produced through people's interactions involving the web and mobile devices. We caught these 'eyes of the world' to investigate visitors mobility in diverse locations such the Province of Florence (Girardin et al., 2008) and Rome (Girardin et al., 2008) in Italy as well as New York (Girardin et al., 2009).

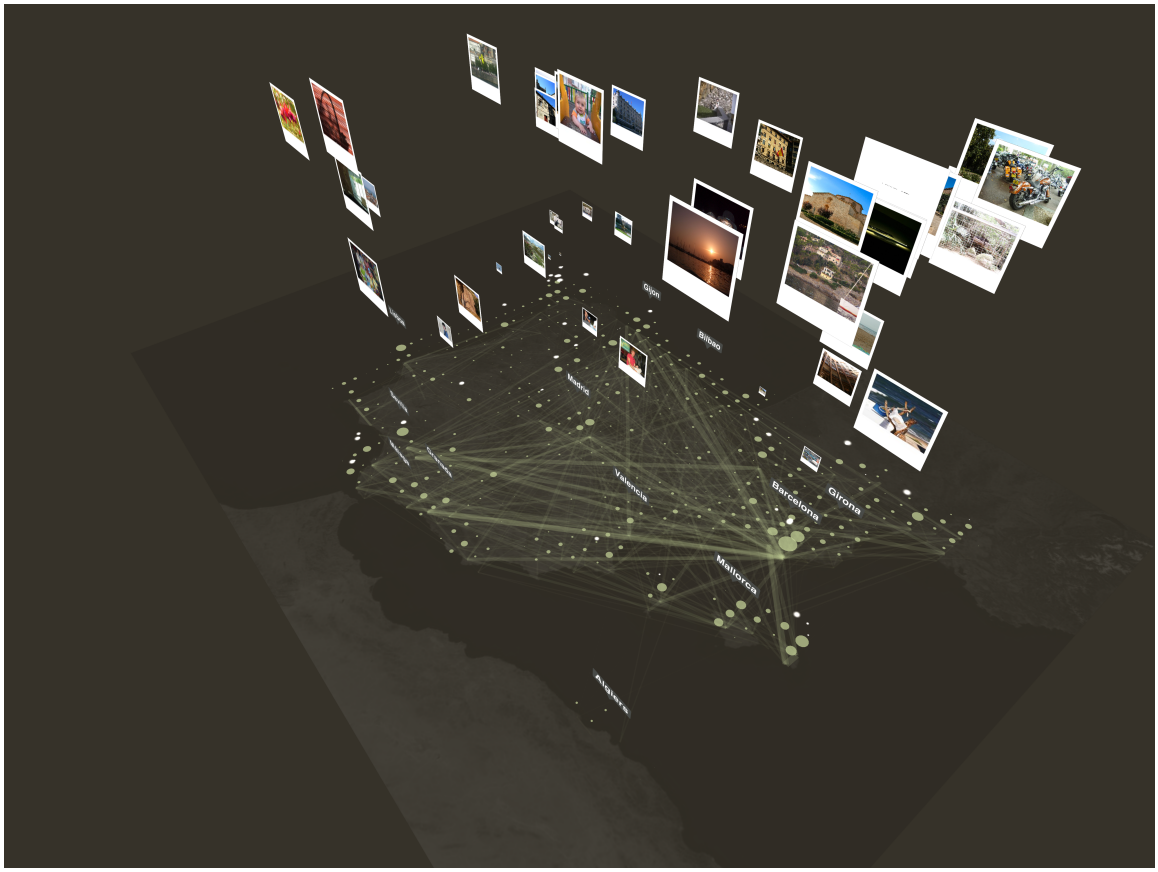

Figure 1: Screenshot of the World's Eyes project exhibited at the Design Museum in Barcelona in 2008. The visualization uncovers the evolutions of the presence and flows of tourists. As photos pill up to reflect the intensity of the tourist activity, they uncover where tourists are, where they come from and what they are interested in capturing and sharing from their visit.

Each time a user anchors a photo to a physical location, Flickr assigns longitude and latitude values together with an accuracy attribute derived from the zoom level on a map. Unlike passive prints, we consider that user-generated content provides unique perspectives on mobility. Indeed, the effort of an individual to take a photo, select it, upload it onto a web-sharing platform and georeference it can be more powerful than any survey or GPS log that researchers interested in human space-time activity could access in the past. There is a very real richness to the 'intentional weight' that people attach to disclosing their photos, and the results clearly show that Flickr users have a tendency to point out the highlights of their visit to the city while skipping over the lowlights of their trip. This "I was here" brings a notion of subjectivity to the relation of people with space and place (Dourish, 2006).

Our work suggests that exploiting this dataset to know who visits different parts of the city at different times can lead to the provision of customized services (or advertising), the rescheduling of monuments opening times, the reallocation of existing service infrastructures or the evaluation of specific urban strategies. From a quite different

perspective, tourists themselves could be aware of the current ways in which they populate the city, and adopt different strategies as a result.

2. FROM THE VISON OF DYNAMIC MAPS OF HUMAN PROCESSES TO THE REALITY

The low cost and high availability of user-generated content now challenges any field that benefit from an in-depth understanding of large group behavior. Indeed, only a few years ago, the possibility to produce fully dynamic time-space diagrams from the fusion of human activities data and novel forms of analysis, was only discussed in the conditional. For instance Zook et al. envisioned in 2004:

When many individual diagrams are aggregated to the level of cities and regions, these visualizations may provide geographers, for the first time, with truly dynamic maps of dynamic human processes. One might imagine them as twenty-first century "weather maps" of social processes.

The presence of active prints suggests that we are at the end of the ephemeral; in some ways we have new means to replay the city and its processes. This potential to replay the city echoes very well with the recent interest of local authorities and urban planners in 'big data'. For instance, tourism is hardly quantifiable because tourists leave minimal tangible traces of their stay. In the World's Eyes, the analysis and mapping of this user-generated content allowed the measurement of the attractiveness of leisure cities and their points of interest. In contrast it also reveals the unphotographed regions still free from the tourist buzz. As photos pill up to reflect the intensity of the tourist activity, they uncover where tourists are, where they come from and what they are interested in capturing and sharing from their visit.

In order to explore that domain, we followed several steps that start from the collection of digital footprints. We used the Flickr API to retrieve the coordinates of photos and their accuracy, the time at which they were taken, and we also obfuscated the identifiers of their owners. Since we were particularly interested in the behavior of tourists, our analysis platform separated the photographers into two groups of locals and visitors based on their disclosed presence in the city over time. For the study of Rome over a 3-year, we collected a dataset of 144,501 geo-referenced photos that had been uploaded by 6,019 different users. With the accumulation of these data we extracted spatio-temporal characteristics such as seasonality, usage patterns, and spatial distribution, main flows of visitors (i.e. desire lines) and the main points of interest of a city

2.1. Presence in space and time

To map the spatial distribution of users, data is stored in a matrix covering the entire study area. Each cell in the matrix includes data about the number of photos taken, the number of photographers present. In Rome, the analysis of visiting quickly uncovers the area's major visitor-attractions such as the Coliseum and the main train station next to Piazza della Repubblica (Girardin et al, 2008). In addition, temporal signatures provide further evidences to the different types of presence that occur at the tourist points of

interest. In Rome, it can be further hypothesized that the Coliseum attracts sightseeing (i.e. photographers) activities over the weekend and the neighborhood of the train station provides facilities for visitors on the move (e.g. people on business trips) during the weekdays.

2.2. Desire lines

The study of digital footprints also enables us to uncover the digital 'desire lines' embodied in people's paths through their visitor of a city or a region. Based on the time stamp and location of photos, our analysis platform organized the images chronologically in order to reconstruct the movement of the photographers. More precisely, we start by revealing the most active areas obtained by spatial clustering of the data. Next, we aggregate these individual paths to generate desire lines that capture the sequential preferences of visitors. The location of each user activity (i.e. photo) is checked to see if it is contained in a cluster, and in the case of a match, the point is added to the trace generated by the owner of the photo. This process produces multiple directed graphs that support better quantitative analysis, enabling us to obtain the number of sites visited by season, the most visited and photographed points of interests, as well as where do photographers start and end their journeys.

2.3. Places of interest

Previous work has demonstrated that spatially- and temporally- annotated material available on the Web can be used to detect "place" and "event" related semantic information (Rattenbury et al, 2007). In a similar vein, the analysis of the tags associated with the user-originating photos revealed clues of people's perception of their environment and the semantics of their perspective of urban space. For instance, the word "ruins" is one of the most-used tags to describe photos in Rome. Mapping the distribution of this tag for 2,866 photos uncovers the most ancient and 'decayed' part of the city of Rome: the Coliseum and the Forum. We used this semantic information to define the main areas of photographic activities as part of an economic impact study of the New York City Waterfalls in 2008.

3. CASE STUDY: MEASURING THE IMPACT OF AN EVENT

In a case study that took place in summer 2008 around the New York City Waterfall public exhibit, we further explored the characteristics of explicit digital footprints to define indicators that measure the evolution of urban attractiveness. The objective for the local authorities was to compare the evolution of the attractiveness and popularity at the different vantage points of the. Therefore, we measured the spatial distribution of locals and visitors and comparing the evolution of the presence of digital footprints as evidences of the positive impact of the New York City Waterfalls on the attractiveness of the waterfront. Eventually, two main results enhanced the City's report on the event: the evolution of attractiveness based on the presence of photographers and the evolution of popularity based on centrality:

3.1. Evolution of attractiveness based on the presence of photographers

According to the relative presence on photographers, our investigation analyzed the variations of attractiveness indicator based on the presence of photographers during the summers of 2006, 2007, and 2008 (the year of the Waterfalls). It reveals a positive growth in the waterfront's attractiveness of 8.2% in summer 2007 and 20.7% in summer 2008 with respect to that of other areas of interest in New York City, such as Time Square and Central Park providing indication of a potential impact of the presence of the Waterfalls exhibit.

3.2. Evolution of Popularity based on centrality

The centrality of an area of interest determines its level of integration to the popular flows of photographers. Our PlaceRank indicator revealed that between 2006 and 2007 the vantage points lost their centrality by 15% while the other areas of interest increased their centrality by 10%. However, between 2007 and 2008, the vantage points gained 56% while the other areas of interest lost 30%. In 2008, the vantage points appear as central as the other areas of interest, meaning that they are on the tourist path as much as the other areas of interest in that section of the city.

This case study provided indications that the emergence of digital footprints creates an opportunity to evaluate in detail the use of space, the impact of events, and the evolution of the built environment. This approach could not only better inform urban design decisions and city management, but also enable local authorities to provide timely evidences to the public about the use of space and about the impact of interventions with the urban fabric. Indeed, the integration of our results in the official study of the economic impact of the New York Waterfalls public art project shows that the indicators proposed by our analysis offered useful measures to complement traditional methods.

4. DISCUSSION

The ubiquitous technologies that afford us new flexibility in conducting our daily activities are simultaneously providing the means to study our activities in time and space. The exploitation of user-generated content to better understand mobility in the urban environment led to several implications we would like to highlight.

4.1. Technical implications

Besides our work on urban attractiveness indicators, other research groups have been using a reality mining approach to derive specific characteristics of urban dynamics (Kostakos et al., 2008, Ratti et al., 2006). A major challenge in this type of approaches is to draw a clear understanding of the boundaries and biases of the data. For instance not to confuse behaviors with endorsement, that can be considered as a limitation of our the New York Waterfalls case study which used the density of digital footprints as indicators of urban attractiveness. Therefore, future studies will need to rely on calibrations with ground truth information produced with proven techniques.

Additionally, some analyses suggest distinct profiles of geo- referencing and geo-tagging photos. These profiles might be based on culture or nationality, the type of tourist in terms of their length of stay or familiarity with the city, their level of technical expertise or spatial orientation ability, an the type of task or type of environment visited. Other

questions that should be considered relate to the types of situations during which users are more or less likely to use their mobile devices for data generation. Answers to these types of questions should allow us to define better the meaning of the data and to explore further their potential usage in social sciences and urban studies.

4.2. Methodological implications

The ability to replay the city shows that there are opportunities for researchers to propose novel ways to describe the urban environment. However, there is a big assumption in seeing the world as consisting of bits of data that can be processed into information that then will naturally yield some value to people. It would lead to what we would call data-driven urbanism, as if urbanism could be driven by data. Indeed, the understanding of a city goes beyond logging machine states and events. In consequence, let us not confuse the development of novel maps from previously uncollectable and inaccessible data with the possibility to produce "intelligent maps". Our work precisely draws some critical considerations on the current state of the art. At this stage we are still trying to figure out: 1) What parts of reality the data reveal? 2. What we can do with them? 3. How to communicate them to people for acquiring information (still a far stretch from "intelligent").

Taken this caution into account, the application of our research approaches seem promising to gain knowledge on the presence and flows of human at a specific space and with particular technologies leading to an approach we would coin as "human/data- based urbanism". It could consist in the use of:

1. The qualitative analysis to inform the quantitative queries: This approach first focuses on people and their practices, without the assumption that something computational or data process is meant to fall out from that. This qualitative angle can then inform a quantitative analysis to generate more empirical evidences of a specific human behavior or pattern. A few approaches in that domain address this perspective. Williams et al (2008) for instance argue that our understanding of the city could benefit from a situated analysis of individual experiences within cities, rather than taking particular urban forms as a starting point for the study of urban experience.
2. The quantitative data mining to inform the qualitative enquiries: In that approach, the quantitative data help to reveal the emerging and abnormal behaviors, mainly raising questions. The qualitative angle then can help explaining phenomenon in situation. The qualitative approaches actually requests to ask the right questions to learn anything meaningful about a situation. An example of the latter could have been applied to the context of the impact of the New York City Waterfalls. We used digital footprints to reveal the variations in spatial presence and abnormal patterns of temporal presence over the course of a 3 years period. In addition to this quantitative analysis we could have performed qualitative observation on the detected areas to reveal how the attractiveness evolves (e.g. Do people stay longer?).

This fosters the need for research and practitioners to develop a coherent understanding of the traces of the activity: both qualitative (e.g. audio and video recordings of action

and interviews) and quantitative (e,g. user-generated content). With significant data on actual use of the space, we can perform new types of "Post-Occupancy Evaluations" often overlooked in the practice of urban design and architecture (Brand, 1995). However, the tools, metrics and interpretation methods are still, for a major part, to be developed.

4.3. Societal implications

Ubiquitous geoinformation are both immensely empowering (for the people and places able to construct and consume them) and potentially overpowering as institutional and state forces are able to better harness information with growing personal and spatial specificity. In consequence there are ethical and privacy implications to grapple with. In conjunction with people's own representation of traceability, there is a legitimate concern on the derive of research on geographically-anchored digital footprints presented in the World's Eyes project. Particularly our work exemplifies the shift from large-scale top-down big brother thread on privacy issues to more local bottom-up little sister types of people monitoring, which makes the whole notion of opting out of technology adoption one of whether to opt out of society.

In fact, these digital footprints have become inevitable in contemporary society and also necessary if we wish to enjoy many modern conveniences; we can no more be separated from it than we could be separated from the physical shadow cast by our body on a sunny day (Zook et al., 2004). The growth of our data shadows is an ambiguous process, with varying levels of individual concern and the voluntarily trading of privacy for convenience in many cases.

In summary, at the same time as ubiquitous geoinformation gives us new means to map and model human dynamics, it will also challenge current notions of privacy. The challenge is to appreciate and use the complexity and richness of ubiquitous geofinformation without crystallizing into authoritarian structures.

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