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Real-time urban sensing and information visualization during city-wide protests and riots: Rome, October 15, 2011

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KEYWORDS *Citizen science, information visualization, natural language analysis, real-time systems, social networks, urban anthropology, user generated content, urban sensing*

PROJECT DATE The project is based on a wider family of projects called ConnectiCity, begun in 2009, Italy. The specific project described in the paper is from 2011, still active in a further stage of development.

URL http://www.artisopensource.net/category/projects/

ABSTRACT We investigated the possibility of capturing real-time user-generated content produced through social networks during city-wide protests and riots. The paper presents the methods and technologies used to capture such content during a series of experiments performed on occasion of the protest which took place in the city of Rome on October 15, 2011. The results are presented here along with suggestions for further research.

For these experiments: user-generated content was harvested in real-time from social networks during the protest and riot, processed using Natural Language Analysis, and geo-referenced using geo-parsing and geo-coding techniques. The information produced from this process was then used in several prototypal usage scenarios in which specific information visualizations and dedicated interaction metaphors were designed to investigate the possibility for transforming collected data into accessible, usable, ubiquitous information.

The paper presents the design process and the results of three specific usage scenarios: a city dashboard for public administrations, a location based system for police and security forces, and an augmented reality application for protesters and citizens. The application for further research and development are also presented, as well as a detailed description of the difficulties and issues encountered in the research. An analysis of the strategies according to which complex information can be visualized and interacted with in emergency crowd scenarios (such as a massive violent riot breaking out within an urban environment), in ways that are effective and accessible are here discussed.

INTRODUCTION

On October 15, 2011, an initially peaceful protest in the city of Rome quickly transformed into a widespread, violent riot. Multiple interpretations have been advanced as to what happened on that day: points of view include strategic, political, sociological, anthropological, and economical causes. The emergence of such powerful and unforeseeable human arousals in cities is a topic of great

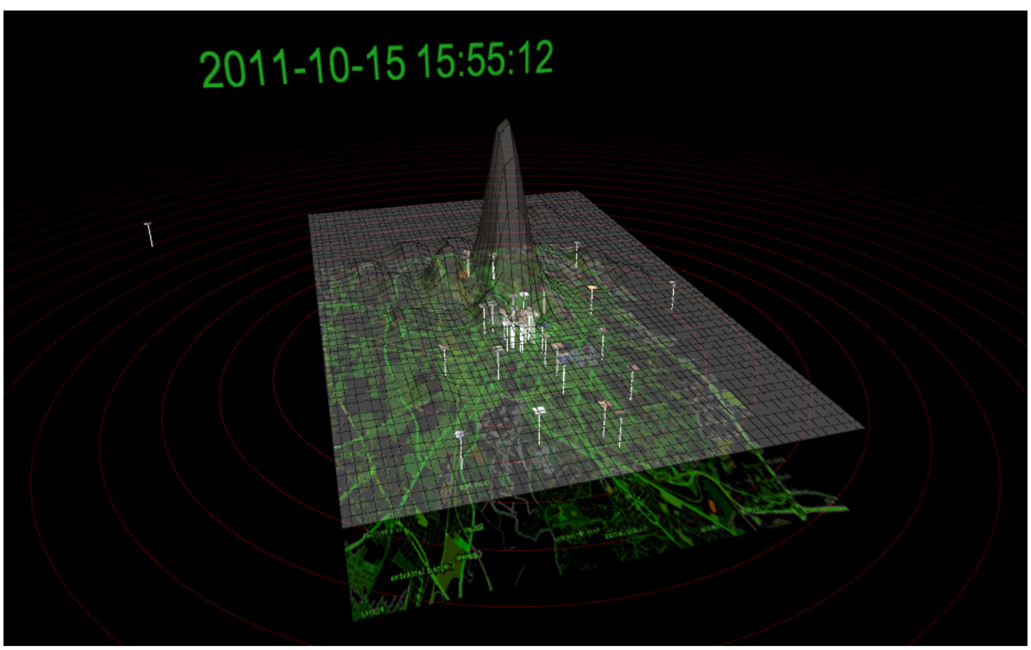

FIGURE 1: *The digital life of the city of Rome during the protest, as it emerged by capturing social media generated by users. These visualizations reveal approximately 95,000 information elements (posts, comments, image labels and descriptions) which have been generated during the protest, from 1pm to 8pm of October 15, 2011 in the city of Rome, in 29 languages.*

interest for scientists, administrators, politicians, security officials and, obviously, the rioters themselves.

As scientific researchers, artists, designers, and communicators, we are naturally and actively inclined observers of human mutation in contemporary times; we are interested in these kinds of events. Understanding the varied, unpredictable ways in which large parts of the citizens of a city activate themselves in unforeseen ways during certain times, such as in emergency scenarios like earthquakes, uprisings, and other traumatic experiences that take place in urban contexts—is a crucial issue in city design and governance. And it provides important insights on the ways in which cities can be envisioned, built and managed, with relevant issues being highlighted for administrators, organizations and citizens.

> *Our lives as human beings and citizens have radically and rapidly changed in the last few years.*

The wide and ubiquitous availability and accessibility of digital technologies and networks has radically changed our perception of space, both private and public.[1] Researches[2] show how the possibility to produce—instantly and ubiquitously—situated digital information allows citizens to embrace constructive processes onto their public spaces, which take entirely new form as they become layered spaces for the expression of multiple points of view. Furthermore, the possibility to access such information ubiquitously, in the place and on the objects for which it has been produced, has radical effects upon our perception of public space.[3] Ubiquitous technologies mutate the way in which we create our understanding of space—even contributing to building the collectively created social affordances of physical spaces. These ubiquitous technologies define our cognition as to what is possible, impossible, suggested, or advised against.[4]

Putting these two levels together (producing and accessing ubiquitous, real-time, digital information in cities) creates a feedback loop which completely transforms the idea of public space and citizenship into more active, aware, informed ecosystems and the human beings within those systems.

For cities, and the emergence of unexpected events of citizen uprisings inside them, it may be understood that through digital life we perceive new contexts for public space—transforming the ways in which we live, work, learn, communicate and relate. The possibility to design and visualize information into understandable, accessible, and instantaneous ways is a key factor to catch the opportunities made available by the scenario we describe.

PROBLEM STATEMENT

What happens in cities during riots, protests, and other forms of exceptional, unforeseen events; what happens during earthquakes and other natural phenomena, or conversely, through planned concerts or fairs, for example? What is actually happening in cities when large amounts of people suddenly and temporarily activate in ways which are violent, fearful, emotional, or excited? How do these kinds of exceptional phenomena reflect on the ways in which individuals and communities experience cities and, thus, move, act, relate and communicate across them?

Furthermore, how is it possible to gain deeper understanding of these processes, possibly in real-time, and to use it to create strategies and practices which can effectively deal with emergences. Is it possible to design cities and public spaces in which they can be confronted with in ways which are creative, effective, tolerant and collaborative? How is it possible to visualize and experience the activity of cities in these exceptional occasions? What visual models and strategies are able to support such expressions? What forms of interactivity can be applied to allow different types of people to navigate and understand information in these contexts? What architectures support precise, expressive, and complete representations of such information?

Furthermore urban protests usually represent exceptional, observable situations in which large numbers of citizens activate themselves almost simultaneously, in ways which can be easily compared to other times when this happens: earthquakes, natural disasters, social distress, war, city-wide traumatic events. In this scenario, understanding the possible ways in which this kind of information can be structured, clustered, and represented is a major issue. Accessibility, usability, bias, understandability of information, and the usefulness of the meanings and narratives that are exposed by each type of visualization must all be appropriately planned and designed, yet leaving space for individual representations to emerge, to explore and construct new layers of meaning and narratives. The choice of aggregates and clusters to be represented, and the consequent narratives which are defined also are a major concern, preserving the neutrality of information, avoiding the aesthetics of visualizations from creating bias, and avoiding being blocked in data exploration by having fixed clustering, filtering and aggregating strategies.

PREVIOUS RESEARCH

A number of previous research undertakings have been performed respecting the observation of the real time life of cities using the possibility to capture citizens' activities performed through digital tools. Some of this research directly assess the observation of city dynamics during protests and other exceptional events. In[5] groups of people are pointed out as beneficiaries of mobile location-based services. In the research, scenarios of coordinated actions, such as protests, are pointed out as particularly significant, indicating how "groups of users can coordinate and adapt to changing environmental conditions—such as protesters during public demonstrations." Additionally, third parties are also described as possible beneficiaries of the information generated in the observation of real-time digital citizen activity in cities, for example in scenarios of public safety and security, or emergency relief.

One very interesting issue which should be noted is Urban System Mapping which leverages the availability of high volumes of location data to dynamically create behavioral maps of the city. This is described as being specifically significant while events in public space are taking place.

An interesting example of the possibilities to capture and map citizens movements and activities in cities is the Amsterdam Real Time project,[6] which aims to construct a dynamic map of the city of Amsterdam based solely on the movement of people carrying a GPS device and being tracked in real time. The underlying idea, developed for an exhibition, is that "every inhabitant of Amsterdam has an invisible map of the city in his head. The way he moves about the city and the choices made in this process are determined by this mental map. Amsterdam Real Time attempts to visualize these mental maps through examining the mobile behavior of the city's users." [7]

A completely different approach has been used instead by Virender Ajmani[8] in the Middle East Protests project. Here users perform the role of mediators of the information regarding the events popping up in the cities which were involved in the protests of Bahrain, Egypt, Libya and Iran, in real-time. Visitors to this tweet-centric display can select one country at a time to view a national map and tweets tagged with the country's hashtag (#Bahrain for Bahrain, #Iran for Iran, and so on). Tweets appear one at a time every five seconds. Depending on tweeters' available geolocation information tweets may appear over different cities around a single country. The map includes tweets from around the world, as well, and is not limited to people on the ground. If, for example, a user in the U.K. tweets about Egypt and uses the hashtag "#Egypt," that tweet appears over Egypt's capital, Cairo.

This example shows the application of an interesting design decision which needs to be assessed while conceiving this kind of system, wether to map users' own geographical locations, or the positions of the places they're discussing about. Following this same concept, using information garnered via "trusted accounts on Twitter," the @Arasmus Twitter user[9] has constructed an interactive Google Map that plots the sites of reported (albeit, unconfirmed) violence in various scenarios of the Arab Spring. According to the L.A. Times, "users select icons on the map to separate reports of protests, police violence and death tolls." Details are also provided for each report. These kinds of systems can be effectively used to suggest active citizen participation processes, such as in the case of Global Berish,[10] which was used to engage people from Malaysia living both inside and outside the country in contributing information and their own take on fundamental issues of public discussion and protest, and also to observe the opinions of other citizens, building awareness and engagement.

Another concept was developed for the MayDay 2012 event taking place in lower and middle Manhattan, New York.[11] In the project, maps plot the when and where of tweets containing the keywords MayDay and Occupy (representing a healthy mix of supporters, detractors, and everybody in-between). The visual coordination of three dimensions of data: location, time, and topic, provides an up-to-the-second profile of a social event as it forms, moves, and dissipates.

The maps shown on the project's website show the Bryant Park staging area as tweets converge around the meeting point, displaying the tight linear trend of the march's progress south to the business district, and finally the dissipation cloud around the NYSE on the same evening. The time profile, meanwhile, shows the buildup of tweets using these keywords, plateauing at the time of overall movement, peaking at the end of the workday, then smoothly dropping off in frequency.

Many more projects and resources of this type have been produced over the last few years and are still being produced now. Three main elements of distinction emerge:

- the usage of open data or other form of data-set versus the usage of user generated content submitted spontaneously either in a integrated way (by, for example, using a specific interface or certain pre-defined hashtags);

- the quantitative versus qualitative approach, in which number and intensities of messaging are used, or their classification according to one or more criteria;

- the usage of platform-provided metadata (such as the geographical position, the language, or the theme of the messages, accessible through operators' datasets or Application Programming Interfaces), or the usage of specific technologies used to infer and extract information from user generated content (for example by using Geographical Named Entities[12] to infer the geo-location the user is discussing, or using Natural Language Analysis[13] to understand messages' expression of sentiments, emotions and specific topic reference).

METHODS

Observing the insights gained from analyzing previous research, and using them to reframe and optimize our initial goals, we set forth in formalizing the methods to be used in our research process. Our methodological approach is based on an iterative design strategy focused on the following steps:

- define the strategic objectives to be pursued in the observation of the digital citizen activity during protests, in terms of types of information, possibilities for clustering, opportunities for interaction and personalization of the tools and views offered to different types of end-users;

- define the logical and physical architecture used to host and represent the information captured during the observation processes, to both support the objectives defined at the previous point and to allow for further expansions, easy sharing and integration toward other practices and the adherence to open, widely adopted standards;

- structure, design, develop and test the technologies needed to enact the real-time information harvesting processes, both in terms of the technologies used, the strategies (including considerations on users privacy and adherence to Service Providers' terms of services), and the technical/technological requirements needed to support different types of harvesting processes, in terms of both size and quality, including the definition of strategies dedicated to scaling the involved systems;

- perform harvesting processes in various types of controlled scenarios, including different cities, languages, urban arousal conditions, or even artificial social networking environments simulated using custom-made software tools to validate, tune and correct both the overall system and its single components;

- conceive, design, test and correct the visualization strategies used to represent information for different types of users, describing a series of application scenarios (including ones for citizens, strategic tools for activists, operative tools for security forces and monitoring tools for administrations);

It is beyond the scope of this paper to go through all the details of all the phases of the methodological approach and their complete description can be obtained.[14]

Here we will focus on the details which define the strategies used to design the information architecture, the type and quantities of data which is harvested in real-time, the filtering, aggregation and clustering strategies used to achieve different results for different types of users, and the visualization strategies used for each of them. The results section will present the outcomes of this process, while in the discussion section we will describe the critical and open issues which will need further research to be applied. The technological brief section will provide detailed information about all the technologies used in the prototypes and finalized products.

Data harvesting was enacted onto the Facebook, Twitter, Foursquare, Instagram and Flickr social networks. Each one of these services provides APIs (Application Programming Interfaces) which can be used to request information in real time from the flow of content generated by each service's users. Each service provides this kind of access along slightly different modalities, with two main different schemes emerging: REST services (application queries the service using an HTTP based request, and the service provides replies in the answer) and stream based services (the so-called "firehose" methodology, according to which the application opens a persistent connection in which the service provider places content as soon as it emerges. Furthermore, information can be requested according to different logics, for example filtering by keyword, by geographical location or by other metadata contained in the messages.

In addition to these, providers serve information using their own format, including different metadata for each content element and custom naming schemes and data dictionaries for similar data.

Among the main issues to be taken into account while harvesting information from social networks is the necessity to respect the legal terms and conditions according to which providers allow other services to access and use their information: among all existing limitations one of the most pressing is the veto for application developers to store the captured information.

To assess all of these issues, a series of steps have been engaged:

- an abstraction layer has been created to encapsulate the differences among all supported services, including differences at protocol levels and the different metadata provided; each social network is handled through a different implementation of the abstract handling component, configuring and establishing the correct communication procedures and processing harvested data towards obtaining information expressed in a common data format;

- harvested data is never stored by the procedures; data is captured, processed and only the relevant information (such as geographical position and extracted sentiment and topic analysis) is kept inside the system together with the identification string provided by the different services, to be able to recall it by using the methods suggested by the service provider's terms of services only when requested by users;

- a common information architecture is created, to store the data which is relevant to the system and to harmonize handling procedures which are specific to each service; this information architecture basically stores geographical positions and timestamps, associating them to the codes of the emotions and topics identified in each data element, and to the identification string which is required to access the content itself using the provider's standard procedures;

- the information architecture also includes data structures to host the data dictionaries which are used to transform provider-specific metadata values into the general, integrated values used by the system.

A server has been created to host the harvesting processes. One main issue faced in its design and development has been the necessity to confront with the bandwidth and processing power needed to capture entire cities' social network data flows. For this a cloud architecture has been designed and implemented, hosted on several different services, allowing to both easily plan and quickly scale bandwidth and processing power according to the requirements and evolutions of the real-time context. Each harvested data element goes through a series of procedures, to extract relevant information from it:

- text elements are compared to the content of a large database of Geographical Named Entities[15] of the location that is being monitored, using specific techniques to understand if the content's author is describing specific events taking place in a specified location of the city (e.g.: the Named Entity is used in specific linguistic structures, such as in "event_X is happening at Geographical_Named_Entity_Y"); a match in this sense produces the set of coordinates which are relevant to the information element; whenever available, users' geographical location is also used to fine tune these results (e.g.: in the phrase "people are doing x in front of the cinema", GPS produced geographical coordinates can be used to infer the exact cinema the user is talking about);

- a Natural Language Analysis engine[16] is used to infer the topics being discussed by the content (e.g.: specific linguistic templates are used to match user expressions, such as in "people are verb_X in front of the cinema", allowing the procedures to identify verbs, nouns and adjectives which can be matched to a database of terms which allows to infer the topic being discussed in the message);

- the system updates according to Machine Learning techniques[17] in both a "learn by example" way (e.g.: power-users mark specific messages as being relevant to a certain topic), and in an automatic way (e.g.: if more than x messages being identified as relevant to a certain topic also share a series of linguistic patterns, then these patterns are added to the dictionaries);

- a sentiment analysis engine[18] is used to infer the emotional approach expressed in the message, from very simple classifications (e.g.: positive, negative, mixed) to more elaborate classifications, when possible (e.g.: fear, anxiety, violence...).

Thus, after these procedures, some of the content generates system relevant information, having this structure:

- geographical coordinates (latitude, longitude) and geographic designation (address, Named Entity);

- a timestamp, describing the time at which the message has been generated;

- a list of topics for which the message is relevant;

- a list of emotions being expressed in the message;

- an ID string, allowing to fetch the original information from service providers in accordance to their terms of services.

The information is, at this point, available for visualization and navigation.

The visualizations have been produced according to a series of scenarios:

- analysis and navigation of the content being produced and harvested, both in real-time and offline

- visualization of the digital activity during the protest

- visualization of dangerous scenarios, from the point of view of a protester

RESULTS

Following the methodological approach, the research produced a series of results:

- an analysis infrastructure, using visualizations to navigate and understand the digital life of the city during the protest, as observed through social media;

- a usage case scenario, designed under the form of a smartphone application with a minimal, highly expressive interface and visualization, intended for use in the middle of the protest, to identify safe escape routes in case of violence;

- a prototype smartphone application which can be tuned to different topics and emotional expressions, and which allows navigating physical space in real-time through user generated content which satisfies specific filtering parameters.

On the map, the images of the user avatars generating the messages in the same time-slot are shown.

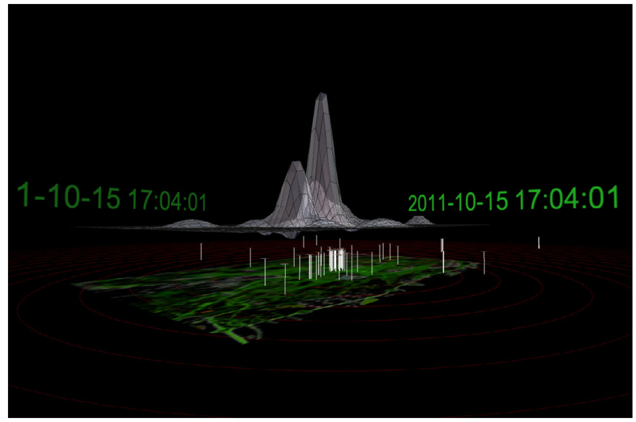

FIGURE 2: *The three dimensional surfaces over the map of the city of Rome show the number of content elements captured in during the 5 minutes around the time shown in the background. The geo-referenced information elements are shown in this representation, and the surface accumulates their number and interpolates the areas with no information in order to create a more composited and easy-to-read visualization.*

A set of tools can be recalled from this interface to:

- select the sources which show up on the map (Facebook, Twitter, Foursquare, Instagram, Flickr);

- enter keywords according to which content is filtered (entering a keyword leaves on the visualization only the messages which contain it);

- navigate the timeline by either time-travelling using a slider to select the instant in time to be visualized, or by selecting a range in time to visualize the information harvested along its extension.

This visualization has been proved to be very effective: during the protests the peaks have closely followed the physical path of the protest, allowing for simple analysis of the expressions and conversations going on in the various parts of the city and also for easy analysis of the relevance of specific themes such as violence, injuries and illegal activities in the different areas and times of the protest. FIGURE 3 (next page) shows an Augmented Reality Interface which was built to assist the protest participants in trying to find safe ways out from the violent situations which are common during riots. The interface shows a minimal, instantly readable, highly-optimized information visualization. Here an arrow assumes different colors as the user points the smartphone in different directions. A red

FIGURE 3: *Argumented Reality Interface depicting areas of greatest intensity of violence.*

color code would indicate that in the specific direction pointed to by the smartphone (and captured using GPS and Compass) a high number of messages have been captured on social network containing information about possibly dangerous scenarios (violence, injuries, beatings, chaos). A green color would, instead, mean that no such evidence has been collected in that direction.

Evaluation is performed in the following way:

- direction is estimated by combining the readings of the GPS, Digital Compass and Accelerometer contained in the smartphone;
- a spatial query is performed on the database to collect the content which has been harvested in the latest 3 minutes inside a geographical area delimited by the user, a 25 degree wide cone centered along the sensed heading and a radius of 500 meters;
- all content is counted and classified according to topics and emotional expression;
- a high number of content elements relevant to the topics of violence, injury and other possibly dangerous scenario would cause the arrow to turn progressively red;
- all other situations would cause the arrow to turn progressively green.

This minimal information visualization has been tested in a simulation in the territory of the city of Rome. The timeline of information captured during the protest has been played back using a custom software which would provide the application the exact information it would have got during the day of the violent riot. Tests have been performed by physically traversing the spaces of the most violent parts of the riot, in Piazza S. Giovanni in Laterano in Rome. Information visualized by the application has been compared with footage captured during the riots by activists and citizens.

Test were made by:

- starting from the via Labicana entrance to the square at 3pm, the time which saw the major parts of the violence start in the square;
- looking at the interface each 5 minutes and choosing to move in the direction pointed out as being the safest one;
- watching a video of the riot which was the closest possible to the time of analysis and to the location in which we arrived after following the application's suggestion;
- comparison between the suggestions of the application (direction and safety level) to the one emerging from the analysis of the videos.

In this test, when specific information was present and, thus, a certain direction was marked as red, the application would report an optimal solution in around 92% of the cases. This figure means that whenever at least a couple of users were pointing out relevant information, 9 out of 10 times following the suggestion of the application would have been a good idea, allowing to avoid the nodes of violence which emerged during the protest.

On the other side, whenever no users provided information (for example when an act of violence had happened and no-one used social networks to describe it in an intelligible way), following the application's suggestions would have been optimal in only 56% of the times.

In the tests, our paths through Piazza S. Giovanni in Laterano benefited from the contributions of almost 1,000 users, totaling around 28,000 messages in a 4 hour time span.

Another application has been derived from the previous one, and it is shown in FIGURE 4 (next page). Here, a compass-like interface sits at the center of the screen. Slices around the circle of the compass shift from green to red to indicate the presence of a selected context in the direction they are pointing to. For example, using the configuration options to tune the interface to react to

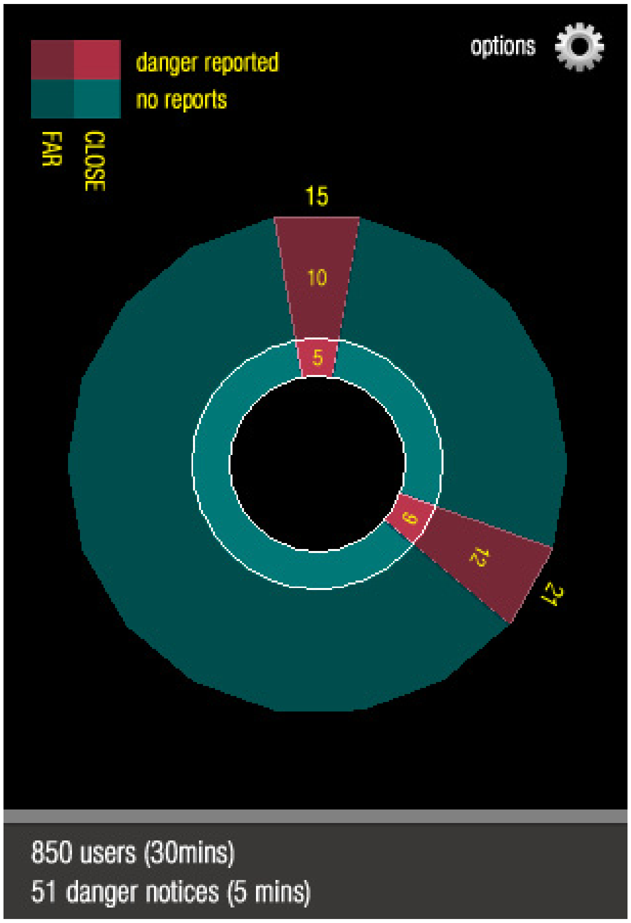

FIGURE 4: *Diagramming relationship between users and danger notices generated.*

anxious people talking about violence, would have made the visualization react to the messages in which people pointed out the danger of a violent activity which would just have been started, or which could likely start in a few minutes from the current time. The interface shows numbers in each slice, showing how many messages are effectively contributing to each interpreted scenario.

A color code based on contrast and brightness also shows the direct relevance of each information to the user: the inner, brighter circle shows the result of the real-time analysis of the messages being exchanged on social networks close to the user, less than 500 meters apart; while the other, less bright circle would show what was happening beyond the 500 meters limit, opening scenarios for look-ahead practices which would combine proximity analysis techniques with wider ranged scenarios.

DISCUSSION AND CONCLUSION

The most pressing issue emerged from the project dealt with the scenarios in which not many users contributed relevant information on social networks. This would happen, for example, when a violent event would emerge from the protest and no-one or very few social network users described it in sufficient detail.

To confront with this problem, we have imagined a series of tools that would enormously simplify the possibility for citizens to contribute to the collective effort of describing the urban context which surrounds them. For example simple, minimal smartphone applications—eventually as simple as one, full-screen button, possibly even operated from inside pockets, without the need to extract the smartphone—which would provide a one-touch notification functionality, tuned to a single topic of interest. For example the “red button” approach, according to which the user could have a single large button to be pressed/touched whenever a dangerous situation of some sort would emerge, eventually providing additional information through voice, thus establishing a basically hands-free natural interaction which would be highly appropriate in such difficult scenarios.

Another issue emerged from the analysis was relevant to the idea of digital inclusion. A progressively higher number of citizens own smartphones and other advanced mobile devices, but it is still not clear how it could be possible to offer the opportunities described in the previous sections to the ones which do not yet own (or know how to use) such devices.

The future directions in which the research presented in this paper will evolve will be:

- the development of strategies which will operate in the area of digital inclusion, providing simple to use, accessible interfaces and also public-space based opportunities for interaction, to enable less technologically savvy citizens to take part in the opportunities and possibilities described in this paper;

- the development of the tools for participation described in the previous paragraphs, to simplify and facilitate meaningful citizen participation in these processes;

- the generalization of the presented systems and visualizations to embrace other forms of traumatic city-wide events, such as earthquakes, revolts and other emergency scenarios, to provide citizens both the possibility to provide real-time, useful information about the dangers present in urban contexts which they inhabit, and ways to overcome them.

Overall, the scenario described in this paper shows the opportunities represented by the possibility to use social networks and social media sites to observe, in real-time and offline, the digital lives of cities in traumatic events; such as would occur with city-wide violent riots. Evidence shows how a high level of digital engagement already exists in citizens, and how they often and spontaneously contribute very precise information regarding important issues of their cities.

Further steps could and should be performed in this direction, by both providing easy, accessible, usable tools which citizens could use to augment their engagement in expressing the conditions of the urban contexts which surrounds them, and to address specific themes using interfaces which are optimized for them, transforming the experience of public space and adding new layers of socially built affordances which would allow other citizens to become more aware, involved and informed.

BIOGRAPHIES

Salvatore Iaconesi is an artist, robotics engineer, hacker and interaction designer. He teaches Digital Design at the Faculty of Architecture at the University of Rome and at ISIA Design in Florence. He is founder and president of Art is Open Source, an international network operating across arts and sciences in the design of novel scenarios for human beings and cities.

Oriana Persico is a communication scientist and artist. She teaches Public and Exhibit Design at the Faculty of Architecture at the University of Rome. She designs and implements events which interweave arts and sciences. As a writer and journalist she collaborates with multiple newspapers, magazines and journals in Italy and abroad.

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