Mobile phone use, events and emergent phenomena

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Abstract

This article is an attempt to approach urban situations events and emerging phenomena, via a study of the deployment of major sporting and cultural events. Data provided by mobile phone use are a unique database for the observation of contemporary urban practices. Information derived from mobile phone use could be a descriptor of urban life. This data casts new light on the chronotopic dimension of places in a city.

Keywords

City, Mobile phone, Events, Chronotopes

Introduction

This article is an attempt to approach urban situations events that are limited in time and space and emerging phenomena, via a study of the deployment of major sporting and cultural events in territories. To understand the scale of change in the city at the time of major events of this type, whether in its

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daily patterns or in the form of ephemeral configurations that emerge, the data provided by mobile phone use are a unique database for the observation of contemporary urban practices. This anonymous data (supplied by the provider Orange) in the form of the recorded traces of mobile phone activity by users present in the city area provide great temporal accuracy (to the minute) as well as spatial precision (relay aerials). The mobile phone, a technological tool that is now widely used in the population, accompanies the daily professional and private lives of city dwellers. We considered that information derived from mobile phone use could be a descriptor of urban life. This data casts new light on the chronotopic dimension of places in a city, and on the realities of variations in the use of the urban space by the inhabitants. A major event, when it occurs, introduces discontinuity in the usual temporal continuum of functioning in the city, and variability in the attractiveness of the intra-urban space. Here we explore both the way in which the traces of an event can be identified from a set of data, and the spatial and temporal threshold(s) beyond which emergent phenomena are observed. In the particular case of two major outdoor events that are free of charge (Armada de Rouen, the events of 2008 and 2013)[1] the aim is to capture the patterns of variation in urban life from data that can provide detailed spatio-temporal sequencing, via positions of mobile phone use in the urban space. The assumption is that global properties emerge from the interaction of the many different components of the system that is formed by behaviours on the part of mobile phone users. These behaviours deploy in an urban environment entailing constraints in terms of mobility or availability, liable to influence potential or likely choices of movement, and, at the time of large events, a variable degree of uncertainty about such movements. Urban events appear to possess the ability to increase intra-urban mobility and to plot out spatial and temporal mobility patterns that are different from the usual patterns of movement of individuals in a city. We hypothesise that the nature of these interactions is neither permanent nor regular in time, and that they evolve in non-linear, non-proportional fashion. One of our lines of research is that of the likelihood of the emergence of self-organising phenomena in crowd movements through the different areas in the city.

An emergent global model: mobile phone messages follow urban patterns of activity

Previous advances and methods

Analyses based on mobile phone provider data have only been used in very few studies. Among the precursors, a MIT team headed by Carlo Ratti first attempted to capture the intensity of mobile phone call flows by using the excess of calls generated by an art exhibition in the city of Graz (Austria) (Ratti, Sevtsuk, Huang, Pailer, 2006). The same research lab also mapped two events in Rome, a concert by Madonna and the triumphant parade of the winning Italian team in the world football championship in 2006. Beyond their actual results, they highlight their "real-time" approach to the city, with perspectives for geo-localisation applications in the functioning of services. In France, the "Orange-Labs" unit for its part observed crowd-gathering patterns in different quarters of Paris during the "*fête de la musique*" (every 21st June) in 2008. The researchers particularly noted the impact on time management and the agendas of individuals using "real time" technologies. These explorations raise the question of the potential occurrence of the unexpected and unplanned within individual routines resulting from "nomadic" means of communication (Aguiton *et al.*, 2009).

Concerning the methods used by this research, in addition to choosing the right statistical indicator to measure crowd gatherings and movements, there is also the question of the spatial base to use for geo-localised records. In line with Candia *et al.* (2008) we chose to subdivide space according to the Voronoi procedure.

Patterns across the city

In the case of the Armada event in Rouen, counts performed on the basis of calls via the Orange provider for the Rouen urban area as a whole in July 2008 and June 2013 exhibit great regularity in the daily pattern of calls on mobile phones[2] from one day to the next. In recurrent way, the patterns and frequencies of calls by users through a given day show 2 main periods for mobile phone exchanges. These peaks are positioned in 2 specific periods in the day, one in the morning, 10 to 12, and the other in the afternoon, 4 to 6 (Fig.1). Overall, this pattern fits professional and domestic timetables on weekdays. The reversion to solely domestic relations, which can be observed at weekends, translates into a drop of nearly 40% in the volume of exchanges, with also a shift in the peak periods to later in the day or night. Text messages, 4 to 5 times more numerous than vocal calls, also exhibit a shift in time, with a very frequent peak of activity between 9 and 10 pm (Fig.2). When applied to different districts in the city defined by the cover of an aerial, it can be seen that they have specific profiles, which are related to classic urban functions. The specific features generally lead to a fairly stable volume of GSM calls over time.

Although potentially subject to marked variations, the number of calls by residents, working populations or visitors remains fairly stable on days and at times that are comparable. We can thus see daily routines in the different districts that are fairly foreseeable if no particular event intervenes to upset them.

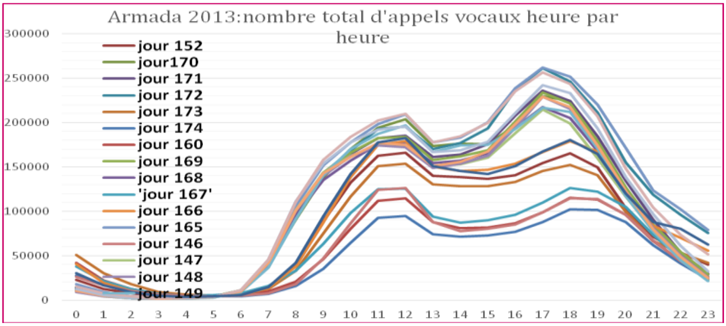

Figure 1 - Armada 2013, total number of voice calls hour by hour over the recorded days

However this overall order is overturned by urban events, the ephemeral nature of which can in certain cases alter the functions or the perceptions of an urban district. There can be events within events – free rock concerts during the Armada, fireworks, parades by the crews, joggers etc. This mixture of the routine and the out-of-ordinary in the urban spaces leads us to suggest the idea of the existence of chronotopes.

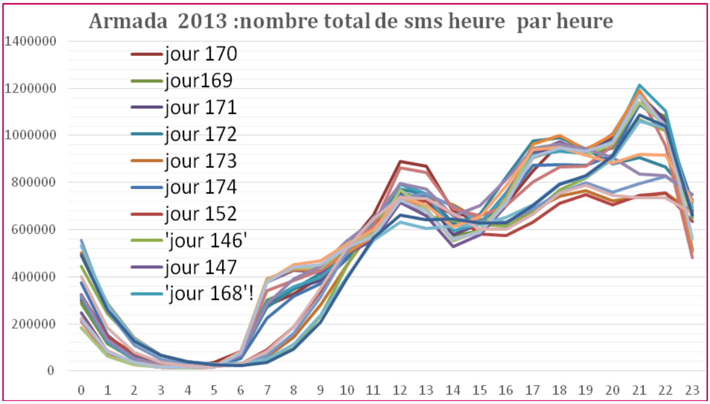

Figure 2 - Armada 2013, total number of text messages hour by hour over the recorded days

Looking for urban chronotopes

This concept was invented by the socio-linguist Mikhaël Bakhtin to identify narrative sequences presenting a degree of unity of place and a specific duration. It was then transposed to the urban space by Mike Crang (2001) and it enables the identification of patterns and cycles in urban life at the time of major events, and this proposal of the notion of "urban pulses" and the "ephemeral city". The pulses are the manifestation of the intersecting temporalities that make up urban patterns. Some of these are routine, while others are atypical, depending on the characteristics of the mobility patterns of city users and on the levels of attractiveness brought to bear by different parts of the city in the course of a day or several days. Using empirical observation of the relative stability of time patterns in urban activity from one day to the next, we then focused on the variability of shifts in intensity in urban activity according to the time of day and according to the district. We attempted to measure this using an indicator measuring the relative "over-frequentation" by users in certain districts.

Measuring the variability of concentrations

The indicator used here measures variations in the spatial concentration of three types of mobile phone user (from Metropolitan France, European Union –without France– and the rest of the world) in different parts of the city: the city centre, the quayside where the Armada event takes place, the rest of the right bank of the Seine, and the left bank. Using a contingency table, it compares the proportion of one category *i* present in a given place *j* (for instance French users in the city centre) with that category as a whole in the city, and this is then compared to the weight of place *j* in all the records for the whole city.

$$\boxed{IndiceF = \frac{\left(\frac{Xij}{X.j}\right)}{\left(\frac{Xi.}{X..}\right)}}$$

where, for a specific category of nationality:

- X_{ij} is the number of users for a given hour *i* and a given day observed in a specific area *j*
- $X_{.j}$ is the total number of users for all days in area *j*
- $X_{i.}$ is the total number of users for a given hour *i* and a given day observed for all areas
- $X_{..}$ is the overall total for all the users and all the aerials over the period.

This indicator thus takes into account of both the weight of each category of user and the weight of each place for a given category. The two graphs below display the phenomena of spatial over- or under-concentration of a category according to time of day and place (Fig. 3 and Fig. 4). It is striking to note the contrast between the underrepresentation of French metropolitan users on the quaysides and the number of French phone users in the city on the one hand, and on the other the overrepresentation of foreigners in the quayside area and in the city centre. This means that for the period of day considered, the number of French users is very small compared with their overall weight across the urban area, while conversely the Armada zone and the historical city centre are rather logically the areas where the foreign users present in the city are to be found. Thus urban practices can be perceived, contrasting the ubiquitous nature of the inhabitants of the city of Rouen with the tropism of the quayside and the city centre for foreign visitors.

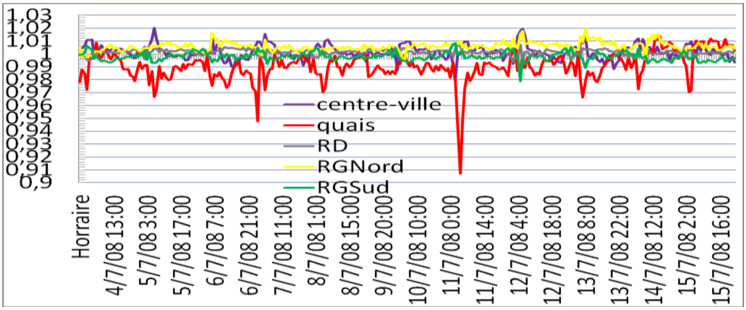

Figure 3 - Over- and under-concentrations of calls by French users according to time of day in 2008

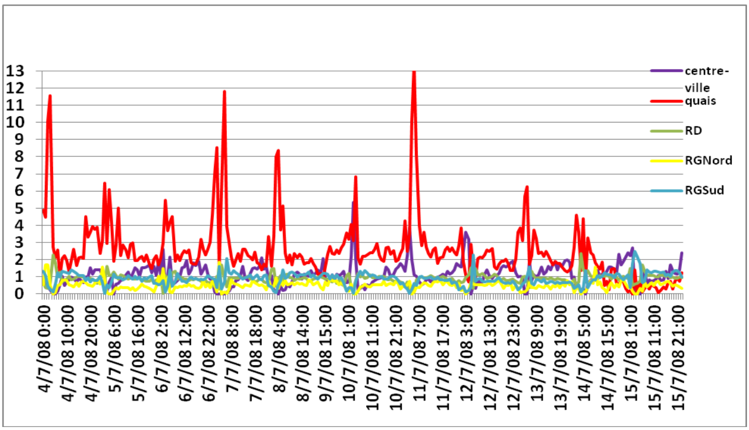

Figure 4 - Spatial concentration indicator for a given time of day in 2008: European Union citizens – without French –

Nevertheless, how far do the mobile phone practices of users present in Rouen during the Armada enable specific behaviours in the public space to be captured? From the recordings of phone uses, some opaqueness in the link between general phenomena and individual behaviours is particularly obvious. It can indeed be seen that the moment of occurrence and the scale of variations in mobile phone activity exhibit no sort of regularity, except that it can be said that non-Europeans tend to communicate late at night (are they celebrating or are they allowing for global time zones?). Whatever the viewpoint adopted, and even if the global level affects individual behaviours, it appears that the observation of individual mechanisms in the system (here the behaviours of categories of users of mobile phones) does not enable an understanding of the overall behaviour of the system. It is based on the existence of a variable degree of uncertainty about movements on the occasion of unusual events.

Spatial autocorrelations and discontinuities

The previous section presented the analyses concerning concentrations of users across predefined districts. Now, rather than using the numbers of users at a given time, we can consider the volume of calls according to different periods and look for the emergence of any grouping into spatial units, and any significant discontinuities between these units. To do this, we used the values of the over-concentration indicator, but replaced the different categories of user by the total volume of mobile phone operations (calls and text messages) for a given day. The contingency table is therefore made up of columns for the different days observed, and, horizontally, the telephone aerials, with their areas of influence delineated by Voronoi cells, following a subdivision of the territory of the urban area of Rouen into Voronoi units. We calculated the spatial autocorrelation between Voronoi units and the overconcentration values. Classically, spatial autocorrelation provides results enabling the degree of resemblance or otherwise between spatial units to be assessed. Here we propose to apply LISA (Local Indicator of Spatial Association) indicators to values measuring the concentration of mobile phone events for different aerials.

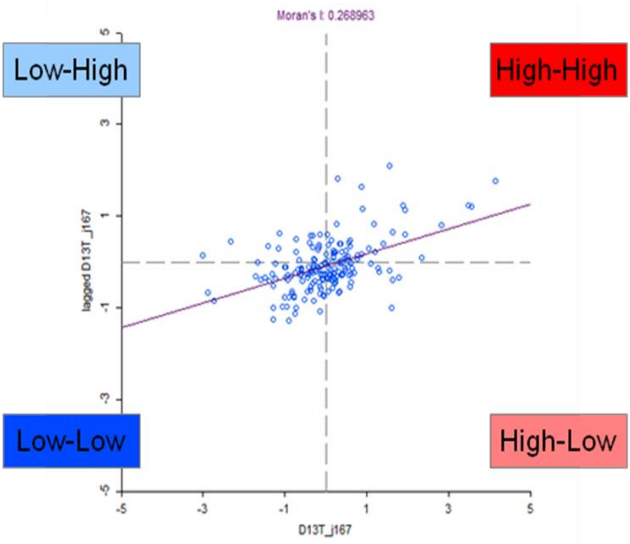

Figure 5 - Diagram showing the four quadrants of possible autocorrelation associations: LISA

LISAs, developed by Luc Anselin (1995), enable the measurement of the degree of resemblance of a spatial unit with neighbouring units. It is thus possible to show general trends, while at same time preserving local values, i.e. preserving the information relating to the internal heterogeneity of these zones.
Thus for a spatial unit *i*, a local autocorrelation coefficient *li* is estimated by *zi*. In our study these are values for the relative intensity of mobile phone calls for a given day in each spatial unit *i*. The sum of the local coefficients is proportional to the global coefficient. The Moran diagram (Anselin, 1995) (see Fig. 5 above) for its part enables local forms of spatial autocorrelation to be distinguished within the overall spatial organisation. This diagram highlights extreme values, and it is possible to assess how far they diverge from the general trend. On the horizontal axis the Moran diagram shows the indicator of overconcentration of

calls for each spatial unit in standardised manner (noted z), and on the vertical axis it shows the spatial difference (noted Wz), that is to say the spatially weighted, standardised mean. This enables two things: an estimation of the overall spatial association (using the slope giving the Moran indicator), and also the local spatial association (using the four quadrants making up the diagram).

The four quadrants make it possible to define two types of autocorrelation, translating either into spatial homogeneity, or into spatial heterogeneity. If there is positive autocorrelation, there will be a concentration of low or high values for a variable. In this case the space is considered homogenous. Conversely if there is negative autocorrelation (random spatial distribution of values for a variable) considerable discrepancies in values for the variable will be observed between neighbouring units, showing spatial heterogeneity and discontinuities. Where the quadrants intersect, the local Moran indicator tends towards 0 and is therefore non-significant. This means that at the centre of the cluster of dots the concentration indicators for mobile phone calls are close to the mean for the urban area on that day, and the same will be true for neighbouring units.

The map derived from the LISA indicator results for the recorded days shows constants in the grouping of the Voronoi cells (Fig. 6, Fig. 7 and Fig. 8).

- In the Armada period, the Voronoi cells of the city centre and the quaysides are in the high-high category throughout the ten days of the event, which means that the autocorrelation indicator with neighbouring cells is higher than the average, and that the values of the concentration indicators for mobile phone calls is also above that for the rest of the period. This part of the city of Rouen thus exhibits exceptional attractiveness, since it combines a classic effect of centrality with an extension towards the quaysides via the influx of Armada visitors (Fig. 7 and Fig. 8)- on weekdays, routine usage and the diversity of function across the different urban districts does not enable significant Voronoi clusters reflecting significant overconcentration of mobile phone usage to be detected.

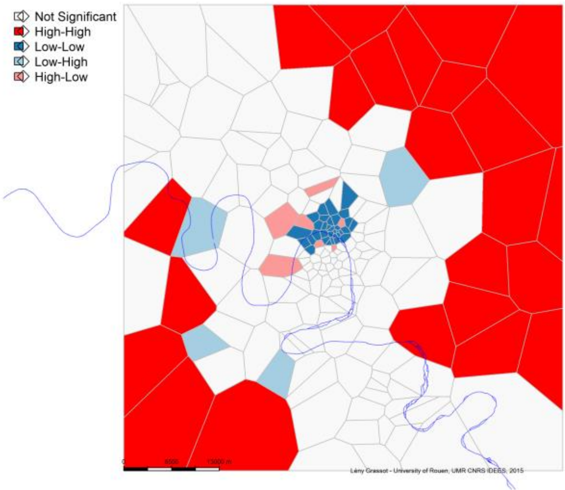

Figure 6 - Sunday May 26th 3013

- On weekdays, routine usage and the diversity of function across the different urban districts does not enable significant Voronoi clusters reflecting significant overconcentration of mobile phone usage to be detected.
- Whether during the Armada period or outside that period, Sundays show marked discontinuities in the results for the LISA indicator (Fig. 6). On Sundays the telephone events linked to professional activities are greatly reduced, and this results in two main types of spatial cluster. On the one hand, the city centre is particularly prominent within an ensemble classified low-low (low values for mobile phone use and low autocorrelation among these zones). On the other, in zones corresponding to the peripheral areas of

Rouen, with mainly residential functions, residents use their day of rest to make calls, generating high-high values reflecting greater mobile phone activity on Sundays than on weekdays.

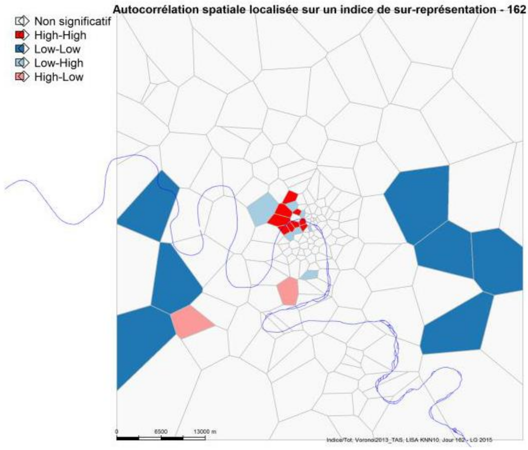

Fig.7- Armada period: Tuesday June 11th 2013

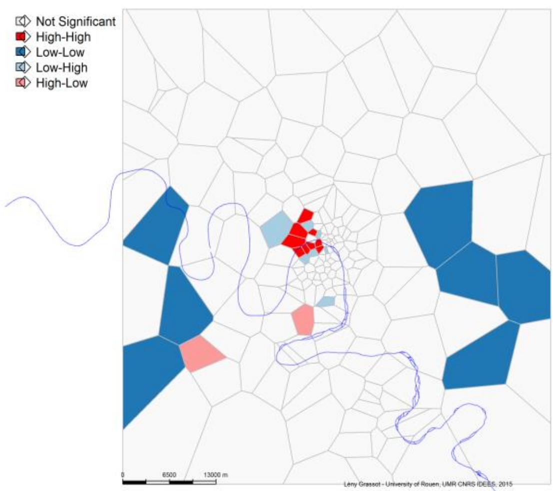

Fig.8- Armada period: Friday 7th June 2013

Using Markov chains, can an Armada effect be seen?

The analysis of the flows of mobile phone users in the urban space of Rouen enables several simple observations which suggest interesting lines of reflection on probabilistic approaches to crowd movements from one hour to the next during and outside the Armada event. The tables below give a picture of the effects of the presence of people from one period to another on a precise grid of the urban space, as well as the volumes of individuals moving from one geographical location to another (Fig.9 and Fig.10). The results of these counts suggest first that there is indeed a certain constancy in the number of people who remain in a given geographical unit from one time period to another, for instance the Seine quayside, or even a degree of spatial "viscosity" seen in the absence of shifts from one unit to another. Likewise, these counts also show flows of people circulating from one unit to another, with these flows presenting different patterns according to the time of day considered. If we adopt a Markov perspective to obtain a better picture of the Armada effect, we can calculate the mean probability of duration of presence or of exit from the quayside area of mobile phone users for the period of the tall ships event. Using these calculations of mobility patterns, it can be seen that there are four iterations forming a cycle from one day to the next, with variable points of departure: T1 corresponds to the 0-8 am period, T2 to 8-12 am T3 from midday to 6 pm, and T4 to 6pm to midnight, while T1j+1 corresponds to 0-8 am the next day and so forth. Markov chain probabilistic analysis casts light on the patterns of stationing within a particular geographical unit in the city and movements from one zone to another. It is indeed possible to see a regular urban dynamic, but also irregularities when the probabilistic Markov results are confronted with the real situation of positions of mobile phone users in the different city areas. Thus it is possible to explore in detail movements from the quaysides and from the city centre.

GAP (M-R) July 13thT1	City Centre	Docks	Right Bank	Left Bank N	Left Bank S
0	0	0	0	0	0
T1T3	-0,13	-0,03	0,06	0,04	0,06
T1T4	-0,13	-0,12	0,11	0,03	0,11
T1T1J+1	-0,21	-0,12	0,13	0,06	0,14

GAP (M-R) July 13thT2	City Centre	Docks	Right Bank	Left Bank N	Left Bank S
0	0	0	0	0	0
T2T4	-0,13	-0,09	0,10	0,04	0,07
T2T1J+1	-0,24	-0,11	0,16	0,07	0,12
T2T2J+1	-0,24	-0,07	0,17	0,06	0,08

GAP (M-R) July 13thT3	City Centre	Docks	Right Bank	Left Bank N	Left Bank S
0	0	0	0	0	0
T3T1J+1	-0,15	-0,10	0,12	0,06	0,08
T3T2J+1	-0,18	-0,05	0,14	0,05	0,05
T3T3J+1	-0,21	-0,01	0,10	0,05	0,07

GAP (M-R) July 13thT4	City Centre	Docks	Right Bank	Left Bank N	Left Bank S
0	0	0	0	0	0
T4T2J+1	-0,09	-0,02	0,09	0,04	-0,02
T4T3J+1	-0,14	0,00	0,07	0,04	0,02
T4T4J+1	-0,19	0,03	0,05	0,02	0,09

Figure 9 - Movements from the city centre: the gap between Markov probabilistic results and real situation for the day of July 13th

Movements from the city centre

The differences evidenced in the table above for the day of July 13th shown in orange represent underestimation-concentration for a given day in the geographical unit and those shown in green represent an overestimation of users in the zone. Thus for July 13th the emergence of minor events can be seen within the main Armada event on the basis of the under- and over-estimations of people in the different areas of the city. For instance, the lower concentration of movements from the city centre towards the quays show tendency to stay in the city centre or on the quayside through all time periods from T1 to T4, and this extends to the next period on the following day for the city centre. Likewise, the over-concentration of movements from the city centre to the quays on the left and right bank provides information on the spatial "viscosity" in the central area of the city in the daytime.

Movements from the quaysides

The differences observed also in the table above for the day of July 4th represent the capability of the quaysides to attract the crowd in this area and keep it in the daytime and particularly in the first part of the night. The orange counts underestimate the real position of users, and so they highlight this pattern of stationing within the quaysides. Movements from the docks to the south left bank of the city shown overestimation faced with the real position of mobile phone users (numbers in green). This overestimation enables less important shifts of crowd from the docks to the left bank of the city.

We hypothesized that the Armada effect could be observed at different scales of observation in the city, that means at the scale of the Voronoï (relay aerials) and at the scale of some largest disctricts in the city (City centre, quaysides, right bank, left bank south, left bank north). Actually, we checked these temporal and spatial variability introduced by an event such as the Armada.

GAP(M-R) July 4thT1	City Centre	Docks	Right Bank	Left Bank N	Left Bank S
0	0,00	0,00	0,00	0,00	0,00
T1T3	-0,01	-0,14	0,06	0,01	0,07
T1T4	-0,04	-0,14	0,05	0,03	0,11
T1T1J+1	-0,06	-0,21	0,09	0,03	0,14
GAP (M-R) July 4thT2	**City Centre**	**Docks**	**Right Bank**	**Left Bank N**	**Left Bank S**
0	0,00	0,00	0,00	0,00	0,00
T2T4	-0,01	-0,09	0,03	0,01	0,06
T2T1J+1	-0,04	-0,13	0,05	0,01	0,11
T2T2J+1	-0,02	-0,17	0,05	0,01	0,13
GAP (M-R) July 4th T3	**City Centre**	**Docks**	**Right Bank**	**Left Bank N**	**Left Bank S**
0	0,00	0,00	0,00	0,00	0,00
T3T1J+1	-0,05	-0,06	0,02	0,02	0,08
T3T2J+1	-0,03	-0,13	0,04	0,01	0,12
T3T3J+1	-0,05	-0,14	0,05	0,01	0,14
GAP (M-R) July 4th T4	**City Centre**	**Docks**	**Right Bank**	**Left Bank N**	**Left Bank S**
0	0,00	0,00	0,00	0,00	0,00
T4T2J+1	-0,02	-0,13	0,06	0,01	0,08
T4T3J+1	-0,05	-0,15	0,07	0,02	0,13
T4T4J+1	-0,06	-0,17	0,08	0,01	0,14

Figure 10 - Movements from the docks: the gap between Markov probabilistic results and real situation for the day of July 4th.

By the relay aerials we verified an Armada effect with the presence of chronotopes, and by Markov chains, we confirmed this effect on a greater scale than relay aerials: i.e. the retention capacity in a geographical area of the town, and abnormalities in the movements of the crowds of a zone to another from one hour to the next.

Development of a simulation platform under Gama

In order to enable the simultaneous observation of mobile phone users and city districts, a simulation platform was developed. GAMA[3] (Taillandier, 2014) is an environment specially designed for the development of spatially identified, agent-based models and simulations. It uses an "object-oriented" language with extensions for the management of agents and their parameters. As in other generic platforms dedicated to the design and simulation of multi-agent models (Netlogo, Cormas, Repast) the user merely needs to describe the behaviour of the agents in a simulation round, and does not need to pre-define the impact of the actions of the agents on the duration of actions performed by other agents. In addition, the platform takes all types of data into account, including GIS data, and enables large-scale simulations (up to several million agents). Using this spatialised development environment, the platform enables models of places and behaviours to be constructed. As each entity is an agent, the non-linearity of the relationships between them can be used to reproduce the realities of urban functioning and those of a major event.

Thus several sets of agents are introduced to reflect the pulsations of the city. The first are the mobile phone users (alias), assimilated to the mobile phones moving across the city, and they are the only mobile agents on the platform. They react to their environment – i.e. to other agents – and also one with the other, and are constrained by their different "personalities", using the space in the manner of real people moving around through the day. Their "personality" is attributed from behavioural models derived from mobile phone data. Under the effect of a range of variables, a succession of spatiotemporal behaviour indicators is formed. Thus the use of the space is approached via information on the use of the territory – the number of aerials used, their localisation, durations of presence, and

also via communication activity: frequencies of connections to the phone network, type of use.
The second set of agents provide behavioural models for the city districts, corresponding here to the telephone network units, defined by the aerials. This behavioural information concerns temporal variations in the attractiveness of the different zones: on a fine time scale, each aerial produces what we could call "pheromones" towards the phone users, encouraging them to draw closer. As the day passes and with the fluctuations of their respective emissions, the aerials pit their attractiveness one against the other in an interplay of attraction and indifference on the part of the user agents.
Finally, there are agents that condition the pulse of the event. The street/road network is thus an agent that constrains the movements of the mobile agents as a result of the capacity of the different sections – speed, number of users, direction of movement etc. This can be completed by topographical information, in particular concerning the fluvial system, which has substantial importance in the territory under study. The Armada take place in a dock area with its quays, and the city in which the event takes place is divided into two by the river.
Assembling these models of behaviour and territorial constraints – street network and waterways in particular) enables scenarios for the functioning of the city and the event to be run. The exploration of mobility opens onto numerous scenarios relating to changes in the traffic network. The example provided by the last two Armada events, with the confrontation of two patterns of functioning involving two different bridges that are main thoroughfares, shows the usefulness of the GAMA architecture – in 2008 the new Flaubert bridge (the sixth and last bridge downstream from the city of Rouen) had not yet been opened to traffic, while in 2013 the event was

constrained by the closure of the upstream Mathilde bridge. The reorganisation and redevelopment of urban spaces was a second major aspect, in particular with the development of a new urban zone - the Luciline district which is developing in the former port area where the Armada has stationed from the outset – including the construction of the Flaubert bridge, housing and office blocks, a large commercial centre and a sports complex.

Conclusion

The analysis of the geolocalisation of users and of their mobile phone use opens perspectives on their ways of appropriating space and on sociability parameters in the city. Unlike the rigid, unequivocal allocations proposed by approaches to the city centred on the functional use of different city districts, the study of the deployment of an event like the Armada in the city provides the opportunity to put greater emphasis on the sequencing of usages of the city according to time and event.

The justification in terms of added value provided by GSM telephone data is, in the case of the Armada, linked to the scale of impact of the event on life in the city. While it takes time to alter or develop urban structures, different festive events take far less time to temporarily transform urban districts and their pulsation. The impact of these out-of-the-ordinary spatial and temporal factors forms an ephemeral city, which deserves as much attention as do lasting urban structures. In this sense, these places that are transformed, and to a degree revitalised, within the time-lapse of an event form kinds of contemporary heterotopias, or "localised utopias" as Foucault called them (1994), removed from the habitual spatiotemporal universe of the inhabitants and the daily routines of the city.

[1] The Rouen "Armada" is a free-entry international event occurring every five years since 1989, in daytime and evenings, lasting through a week of festivities for the general public. This worldwide gathering of some 50 "tall ships" and other vessels along the river Seine quayside affords the opportunity for the public to go on board and meet crews. Along the 7 km of quayside where the ships anchor stalls are set up for refreshments and souvenirs, along with play activities for the children. Every evening there are free concerts, from 6 pm to 2 am, and fireworks around 10 pm.

[2] This concerns outgoing and incoming calls and text messages captured by a geolocalised aerial.

[3] GAMA enables the implementation of an explicit spatial and/or temporal environment (integration and exploration of base maps of the ArcGis type; exploitation of temporal information, such as the passage of time). It completes its user interface by integrating the possibility of particularly sophisticated graphic presentations (2D, 3D, dynamics, interactivity, multi-display etc).

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