Mobility Data as a Proxy for Urban Vitality

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Summary

In this paper, we propose an innovative approach to Jane Jacobs's concept of diversity and vitality, analysing spatial big data to obtain quantitative measurements of urban qualities frequently employed to evaluate places. We use mobility data collected from public transport to calculate a diversity value for each research unit. Diversity is composed by three dynamic attributes: intensity, variability and consistency, each measuring different temporal variations of mobility flows. Using various datasets as proxy for activity density to validate results, we then use a regression model to establish the relation between diversity and vitality and unveil which are the most lively areas in London.

KEYWORDS: spatial big data, mobility flows, urban vitality, temporal patterns, urban geography.

1. Introduction

The recent explosion of available spatial big data from different sources represents an unprecedented opportunity to unveil and understand urban phenomena from a quantitative perspective. These new forms of data empower urban research to infer quantitative evidence and information in relation to spatial qualities that have been so far measured by empirical and sparse observations. The fine granularity of data contained in recent datasets allows to investigate phenomena at a much larger spatial and temporal scale than before.

However, little research has focused on analysing the fine-grained heterogeneity in spatial activity that deviates from the large scale geographic trends that have been known and understood for decades. Few have attempted to connect data analysis to spatial applications that could support urban planning and strategy with valuable quantitative information. Spatial big data could usefully supply for the lack of large detailed datasets that traditionally affects urban disciplines. In this paper we describe how data can be used to quantitatively describe spatial qualities as urban attractiveness, liveliness or vitality, fundamental for disciplines such as urbanism and spatial planning.

2. Urban vitality: definition and current work limitation.

Urban vitality is frequently mentioned by urban researchers and designers as an important quality concerning urban space, and in particular lively places.

A well-known definition of urban vitality is proposed by Jane Jacobs in her book "The Death and Life of Great American Cities" (1961). She considers urban vitality as an essential requisite for a successful city in term of street life, specially associated to safety and walkability. "An intricate sidewalk ballet (p.50)" of people walking around neighbourhoods, in different times for different purpose, is what makes an urban place successful and safe.

Jane Jacobs strongly ties the concept of vitality to that of diversity, which she understood mainly in terms of morphological diversity, associated to the built form of the city and the distribution of activities. She identifies four conditions of diversity (mixed used, age of buildings, number of street

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intersections and urban density) for evaluating vitality: they are essential and complementary to each other, contributing together to define the degree of diversity (and therefore vitality) of places.

Urban studies have widely applied Jane Jacobs's idea of vitality, also to validate it against case studies using small but very detailed datasets collected through empirical observations. Recently some works attempted to validate these concepts through the four morphological parameters at a larger scale, using extensive datasets and new data sources (Sung et al., 2013; Sung et al., 2015; De Nadai et al., 2016).

These analyses have one common main limitation: they do not consider how vitality varies over space and nor over time. However, Jane Jacobs' definitions are explicitly spatiotemporal, stating that the two essential aspects defining vitality are:

a. the continuity of activity, life and presence of users at the city and street level;
b. the quality of flows and users.

These aspects both point to the fact that it is not only a matter of simple intensity of flows of users and activities, regardless of the time distribution: the continuity of flows, its variations in terms of intensity and duration, are very important. Furthermore, the quality of flows, meaning its heterogeneity in relation to users and purposes involved, is also relevant: a mix of different activities working in synergy to attract users in the same urban spaces.

3. Measuring urban vitality: an alternative approach.

Differently from previous approach, we propose to analyse diversity of mobility patterns in order to evaluate vitality and its variations in space-time distribution.

Diversity is represented by spatial and temporal differences in mobility patterns amongst places, calculated at one-hour intervals during week and weekend days. Diversity is defined by three complementary attributes – intensity, variability and consistency – each one representing a different granularity in temporal variation, and together contributing to a value representing how diversity temporally changes over the same urban place, and the variation of activity density (vitality) over place.

We used a dataset provided by Transport for London: a collection of transaction records of the smart card (Oyster card) used for entering, exiting and alighting on public transport in London. The dataset consists of nearly one month of individual records, displaying the time and location of each single transaction, collected during 2014.

3.1. Defining research unit

This preliminary phase has two main objectives:

a. we define the spatial area of interest as composing the tube/railway stations and bus stops close enough (within 5 minutes buffer) to be considered a single transportation entity;
b. we assign to each station and bus stop a coefficient to normalise the mobility flow intensity in relation to the centrality of their location. We select a measure representing centrality in relation to the global scale of the city, the 'integration' measure from Space Syntax (Hillier et al., 1993).

3.2. Calculating diversity

Instead of the four morphological attributes that Jacobs defines as conditions for diversity, we define it by three dynamic components: intensity, variability and consistency. These three attributes contribute to the final measure of diversity (Dv) following the relation described in Equation 1:

$$Dv = \text{intensity (I)} + \text{variability (V)} + \text{consistency (C)} \quad (1)$$

where:

a. Intensity (I) is defined as the number of users in the tube station or bus stop at a defined time interval: it is calculated hourly for each day, and then normalised using the integration score assigned to each point, as explained in paragraph 3.1.

b. Variability (V) is defined as the difference of user flows amongst different days for each station and bus stop. In general, variability tells us the stability of temporal patterns of flows. The higher the variability, the more random the user flows distributed. It is calculate by compare correlation of flow vectors of any pair of days, and then normalised by the number of pairs. Saying, if the number of day is 5, then there will be 10 pairs of comparison (Zhong et al., 2016).

c. Consistency (C) represents the hourly flow variation within the same day for each station and bus stop: this is to verify if they presented a steady temporal profile (constant use through over time) or one characterised by concentrated peaks (use more concentrated into specific hours). We calculated outliers using MAD (Median Absolute Deviation), then normalised against the daily number of outliers per station.

3.3. Linking diversity and vitality

Finally, we evaluate the relation between the diversity measure (Dv) and vitality for each research unit, using linear regression. To validate results, we employ various datasets, each one representing activity density from a different perspective.

We use a dataset of geo-tagged tweets, collected from January to March 2016 for the city of London. Tweets have been assigned to the respective research unit, and we then run the model for an average week day and weekend day for each research unit. We also run the model with other datasets, one collecting Points of Interest (POI) from OpenStreetMap, and one with activity venues extracted from the API of Foursquare: the latter also contains information about the popularity of each venue, therefore adding supplementary information to the relation with vitality measure.

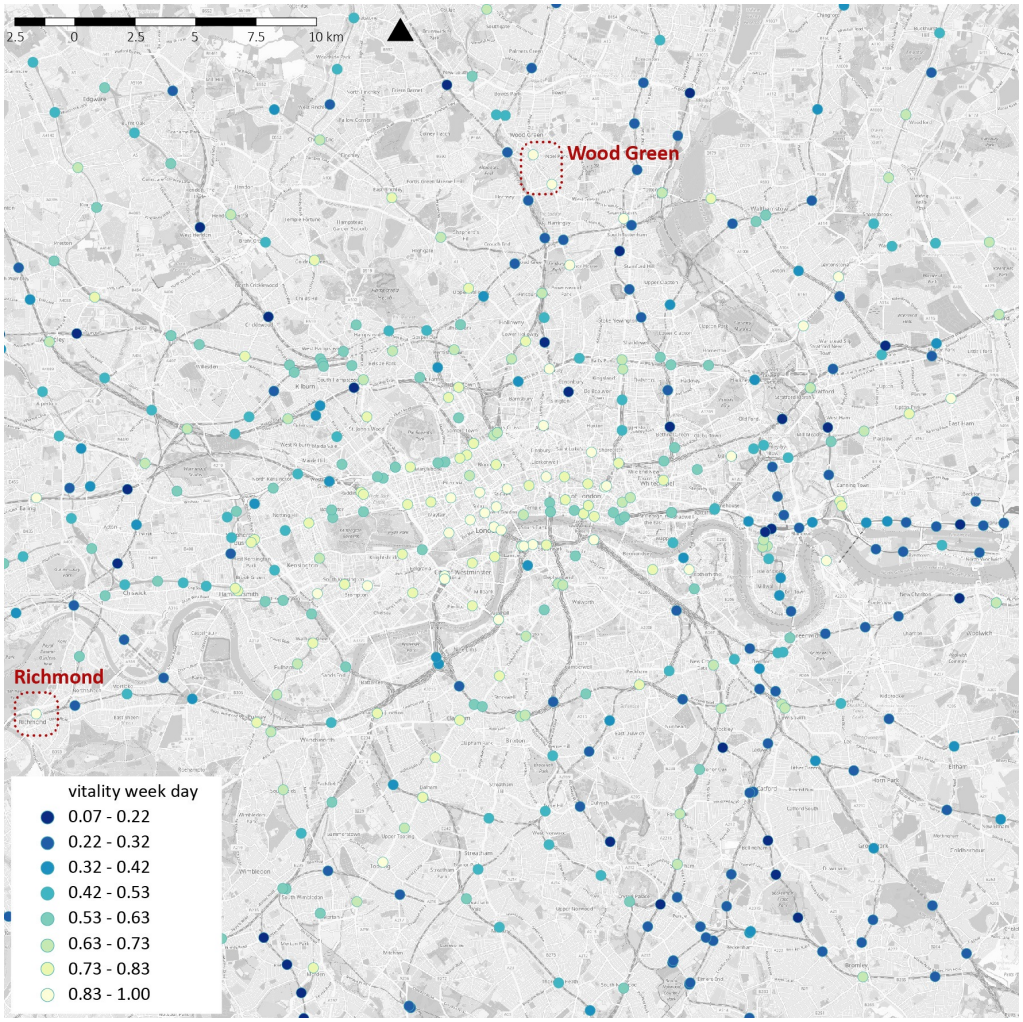

Figure 1 Vitality values calculated for an average week day for each research unit.

4. Results

Results show the most vital areas of London (in light yellow) according to different times of the day and during the week (Figure 1). The fine temporal granularity of the data used in the analysis allows to observe meaningful variations in terms of flows and mobility diversity across London, which significantly help to understand in a more detailed and quantitative way how spaces across the city are differently used over time.

Results for some areas were expected, based on empirical knowledge: this is the case of central London, and the main multimodal train stations (London Bridge, Waterloo, Victoria). However, other areas show interesting behaviours and would require deeper analysis. In particular, some places (highlighted in red) show a clear discontinuity in comparison to the adjacent zones, as Richmond, or the area including Wood Green and Turnpike Lane Underground stations.

It is worth mentioning that this works also includes bus records, which could explain some of results outside the central area of the city, since Underground and train stations act as attractors of bus flows from the surrounding areas.

5. Conclusion

In this paper we proposed an innovative application of the concept of urban vitality defined by Jane Jacobs, using mobility data as a proxy for measuring diversity and vitality for the city of London. We were interested in obtaining a quantitative evaluation of urban qualities (as these defined by Jane Jacobs) frequently employed by urbanism or spatial planning. Although they have been evaluated empirically in previous work, we have demonstrated that it is possible to develop metrics using datasets that not necessarily refer exclusively to the morphology of places.

Our work was also an attempt to apply big data analysis to specific needs of spatial planning and strategy, using a solid theoretical framework that drives research instead of the approach of data-driven research, which has been commonly used from other scientific disciplines dealing with spatial big data.

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7. Biography

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