Applied Geography 75 (2016) 36–48

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Redefining Chinese city system with emerging new data

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ARTICLE INFO

Article history:
Received 25 January 2016
Received in revised form
25 July 2016
Accepted 2 August 2016
Available online 17 August 2016

Keywords:
Urban morphology
Urban function
Human activity
Street network
City evolution

ABSTRACT

Modern Chinese cities are defined from the administrative view and classified into several administrative categories, which makes it inconsistent between Chinese cities and their counterparts in western countries. Without easy access to fine-scale data, researchers have to rely heavily on statistical and aggregated indicators available in officially released yearbooks, to understand Chinese city system. Not to mention the data quality of yearbooks, it is problematic that a large number of towns or downtown areas of counties are not addressed in yearbooks. To address this issue, as a following study of Long et al. (2016), we have redefined the Chinese city system, using percolation theory in the light of newly emerging big/open data. In this paper, we propose our alternative definition of a city with road/street junctions, and present the methodology for extracting city system for the whole country with national wide road junctions. A city is defined as "a spatial cluster with a minimum of 100 road/street junctions within a 300 m distance threshold". Totally we identify 4629 redefined cities with a total urban area of 64,144 km^2 for the whole China. We observe total city number increases from 2273 in 2009 to 4629 in 2014. We find that expanded urban area during 2009 and 2014, comparing with urban areas in 2009 are associated with 73.3% road junction density, 25.3% POI density and 5.5% online comment density. In addition, we benchmark our results with the conventional Chinese city system by using yearbooks.

1. Introduction

Cities, used to be as simple as spatial entities surrounded by city walls in ancient time, have been getting increasingly complex. For instance, the total number of Chinese cities has increased from about 100 in 1949 to 653 in 2014, not to mention the frequent spatial adjustments of a single city (Wu, Long, Mao, & Liu, 2015). A universal difficulty for urban studies is how a city can be defined properly (Batty, 2006; Krugman 1996). There are several lenses to look at a city, morphologically, functionally, and administratively. **From the morphology dimension**, a city can be defined as an area with a minimum of population or continuous built-up area. For instance, Densely Inhabited District (DID) in Japan indicating a city whose population density is over 4000 people per km^2 is a similar concept. Urban areas in UK are derived from constructions-built areas where certain real-estate densities are detected in satellite images or other datasets (Hu, Wu, Xiong, & Pan, 2008). **From the functional dimension**, a city can be regarded as a functional urban area with a dense core and peripheral area as its commuting catchment (Cottineau, Hatna, Arcaute, & Batty, 2016). For instance, labor force markets and commuter sheds are utilized to represent Metropolitan Areas (MA) in US (Berry, Goheen, & Goldstein, 1969). The morphological and functional dimensions have been widely adopted by cities in western countries, and administrative dimension representing for the political and management territory applies to almost all cities on the planet. Rather than from morphological or functional dimensions, modern Chinese cities are defined **from the administrative view** and classified into several administrative categories ranging from municipalities, prefectural level to county level, due to lack of sufficient data and their historical path dependence. Hence, it makes Chinese cities inconsistent with their counterparts in western countries. While the administrative level and extent of each Chinese city was consistent with its spatial power and form in its initial stage, we see increasing mismatches between the administrative definition and the spatial dimension of Chinese cities.[1]

Concerning the administrative dimension governing the definition of existing Chinese cities and being not able to access fine-scale

[1] We also notice the notion of "Natural Cities" proposed by Jiang and Miao (2015). Natural city is a product of the bottom-up thinking in terms of data collection and geographic units or boundaries, which can be extracted from remote sensing images, GPS and location-based social media data.

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http://dx.doi.org/10.1016/j.apgeog.2016.08.002
0143-6228/

urban data, researchers have to rely heavily on statistical and aggregated indicators available in officially released yearbooks (Deng, Huang, Rozelle, & Uchida, 2010; Mao, Long, & Wu, 2015), as well as remote sensing images (Liu, Zhan, & Deng, 2005), to understand the Chinese city system. On one hand, the indicators of yearbooks in China are generally gathered in a bottom-up manner and reported by the staff in each city, thus making the inconsistent data quality across cities due to various reasons like the variations on training level of staffs or technology developing levels among cities. Not to mention the everlasting criticism on data quality of yearbooks, it is problematic that a large number of towns or downtown areas of counties, which should be regarded as cities from a general view of built-up area continuity and population scale, are not addressed in yearbooks (termed as "invisible Chinese cities" or "neglected Chinese cities"). Some large cities like Beijing should be regarded as several separated cities in the commonly accepted definition on cities. In addition, city size is not directly linked to its administrative level as well. On the other hand, those studies using remote sensing-interpreted expansion on understanding urbanizing China still rely on the aforementioned problematic administrative dimension of Chinese cities. Therefore, to address these issues on existing Chinese city system, redefining Chinese city system is urgent for both researchers and decision makers.

The spatial dimension (urban area pattern) is an important view for understanding a city system. An overall review on existing methods for mapping urban areas is available in the second section of Long, Shen and Jin et al. (2016) and the first section of Zhou (2015). These methods range from remote sensing images, population census, settlement and building data, points of interest (POIs),[2] volunteered geographical information (e.g. Flickr photos and Twitters with geo-tags) to road network. Most of the applications of these existing methods in China, if not all, map urban areas for the existing administrative-oriented city system and do not consider redefining Chinese city system. For instance, Long et al. (2016) provide a straight-forward method for allocating urban areas according to urban area totals prescribed in not-always-reliable yearbooks. In this paper, our methodology will not rely on urban area totals prescribed in yearbooks and extract national wide urban areas using road junctions with a bottom-up method.

In this paper, we develop a framework for redefining the Chinese city system from the views of urban morphology, function and human activities by using percolation theory in the light of big/open data. Nowadays, big data and ubiquitous open data from the governments, commercial and social network websites are increasingly available to researchers, and the new data environment is providing more avenues for quantitative urban studies (see Long and Liu (2015) for a review). In such a background, aiming at providing an alternative view on the Chinese city system, we propose our definition of a city with road junctions. Our road-junction oriented city system using percolation theory is more like population center classification system, if we consider a city with many road junctions can be regarded as a city (similar with the minimum population control for a city). We then present the methodology for extracting city system for the whole country with national wide road junctions as well as the results of redefined Chinese city systems in 2009 and 2014, respectively. In addition, we discuss the findings on (1) evaluating the redefined Chinese city system in terms of size, pattern, scaling, hierarchy and temporal evolution, (2) understanding the evolution of the Chinese city system during 2009–2014, and (3) benchmarking our results with the conventional Chinese city system by using yearbooks.

This paper is structured as follows. Section 2 describes the adopted methodology. The used datasets and their results are introduced in Section 3 and 4. Section 5 makes concluding remarks and propose discussion on this study.

2. Method

2.1. Deriving urban areas with road junctions

Considering the data availability and approach reproducibility, we refer to the method proposed by Masucci et al. (2015) for deriving urban areas using road junctions. The approach has been successfully applied for the city system in Britain. In this paper, all road junctions in a large region are partitioned into various clusters by using an elementary clustering technique, which considers two road junctions belonging to the same cluster if their distance is below a given distance threshold (Fig. 1). An increasing threshold enlarges the size of generated clusters, until eventually a very large cluster appears spanning the whole road network. We then calculate the size of the maximum cluster in terms of number of road junctions as a function of the threshold. For all the cities, the size of the maximum cluster has proved to grow exponentially. Eventually, the growth slows down and the curve condensates to a certain value (Masucci et al., 2015). The condensation threshold can be used to derive urban areas of various cities (clusters actually). The condensation threshold of about 300 m was observed in the Greater London. The details for this process are available in the appendix of Arcaute et al. (2015).

2.2. Redefining city system

In this sense, we redefine a city is a spatial entity which (1) consists of a cluster of adjacent road junctions within a predefined distance (morphological requirement for a city system). The condensation threshold is used as the clustering distance; (2) associates with at least 100 road junctions (minimum size requirement, 4 km generally). Each city is then associated with a group of road junctions. The size of each city can be regarded as the total number of road junctions, which has been proved to be significantly correlated with the built-up area of the city (Jiang & Jia, 2012; Masucci, Stanilov, & Batty, 2013).

To derive city spatial distribution, we should convert road junctions of each city into polygon(s) to represent urban areas of the city. The polygons stand for the triangle network composed by road junctions. This can be done by using the toolbox Aggregate Points in ArcGIS. In this process, we use 500 m as the aggregation distance, which is defined according to a trial-error procedure.

2.3. Evaluating redefined city system and its evolution with open data

The redefined city system can be evaluated from geometric, morphological, functional and social dimensions sequentially. From the geometric dimension, the size, boundary, and scaling characteristics of redefined cities can then be evaluated. Since the morphological evaluation focuses on the spatial organization of road junctions in every city, indicators like road junction density can be used to reflect the urban block size pattern (urban design) to gain a big picture of urban spatial structure. Considering that every POI reflects one type of urban function like dining, shopping, education, public administration, etc, the functional dimension pays more attention to using POIs in order to understand urban functions of each city. We can use the total POI density and the POI density of each type to evaluate the degree of maturity for every

[2] According to Wikipedia, "a point of interest, or POI, is a specific point location that someone may find useful or interesting" (https://en.wikipedia.org/wiki/Point_of_interest).