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A multi-scale approach to exploring urban places in geotagged photographs

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ABSTRACT

User-generated content (UGC) that contains spatial references, often referred to by the more bounded concept of Volunteered Geographic Information (VGI), is often touted as a potentially revolutionary data source for geographical research. This paper explores the capacity of one increasingly prevalent source of these data, geographically encoded photographs, to capture spatial expressions of place in an urban environment. Geotagged photographs were obtained from the Flickr API to build a geographic database of photographs for the city of Vancouver, Canada from 2001–2012. These data were aggregated to multiple geographic units represented as hexagonal lattices. Spatial patterns of photo aggregation were examined for tessellations that ranged from 0.25 ha to 1024 ha. Tags associated with each photo were also explored through the notion of 'tag-space' at multiple resolutions, or "scales", of analysis through local log-odds ratios. Results indicate a significant interaction between tag-space semantics and spatial aggregation which suggests that consideration of scale effects should be integral to analysis of this type of tagged VGI for exploring citizens' sensing of urban environments. The results indicate further that we may have to reconsider the interaction between encoded meaning, the methods used for extracting such meaning from tag-space, and exogenous and endogenous spatial scales of spatial UGC.

1. Introduction

User-generated content (UGC), information or media that citizens use, create, and share online, has evolved from what many viewed as a curiosity or a passing technology-led fad in the early days of the Web 2.0 era to now being recognized as an important element of many government, business, scientific and social processes (Elwood, Goodchild, & Sui, 2012; Hermida, 2010; McKenzie et al., 2012; Shirkey, 2008; Tapscott & Williams, 2006). Increasingly, the production and communication of information and knowledge are becoming more collaborative and rooted in networked communities as the distinctions between data users and data producers and, by extension, experts and amateurs are blurred. A small, but growing proportion of UGC contains geographic information either in the form of explicit spatial coordinates generated from personal locational devices (e.g. mobile phones, GPS units, etc.) or less explicit references such as names of landmarks, regions or cities.

Some forms of spatial UGC, such as users' mapping of animal sightings, drivers' reports of potholes in roads, and citizens' comments on land management issues, have direct linkages to specific data products, community interests or "citizen science" initiatives (Connors, Lei, & Kelly, 2011; Wiersma, 2010). This spatial subset of UGC is often referred to within the GIS and GIScience literature as Volunteered Geographic Information (VGI) community following Goodchild (2007). The linkages are less evident with other forms of spatial UGC (e.g. photos, videos and Twitter posts with geographic references) that are typically created simply as an outflow of personal interests or web-based communication and may not be not viewed by their authors as geographic data in their own right (Feick & Roche, 2012; Purves, Edwardes, & Wood, 2011). With much of the social web now enabled with location sensors, the social web is fast becoming the social geo-web (Sui & Goodchild, 2011), and geographers and others have expressed great interest in the opportunities and dangers associated with these vast new sources of data (e.g. Wilson, Gosling, & Graham, 2012).

A prime example of the spatialization of social-web interactions is the proliferation of production and access to digital photographs encoded with geographic information and the subsequent exploitation of these repositories for exploratory, national and global-level research (Crandall, Backstrom, Huttenlocher, & Kleinberg, 2009; Zhang, Korayem, You, & Crandall, 2012). Much of this research has centerd on exploring what types of information can be derived from the growing volumes of geotagged photographs (GTP) that are uploaded and shared on sites such as Panoramio, Instagram and Flickr (Antoniou, Morley, & Haklay, 2010; Kennedy,

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Naaman, Ahern, Nair, & Rattenbury, 2007). GTPs are comprised of a georeferenced image and a set of descriptive keywords or tags that users add to describe the photo, the place or event it is associated with, or its personal meaning. Since users determine what they photograph, what tags they use, and which photos they share, GTPs hold promise as a rich data source for investigating how people perceive and characterize the phenomena they photograph and, potentially, for uncovering hidden geographies and spatial structures in social processes (Ferarri, Rosi, Mamei, & Zambonelli, 2011).

In this paper, we propose a multi-scale method for exploring patterns in the spatial and thematic content of GTPs. Our intent is exploratory in nature and is directed at distilling new insights or hypotheses concerning localized, or scale-dependent, expressions of place that are encoded within individuals' GTPs. We build upon a sizeable body of research centered on GTPs including recent work that investigate: concepts of place and vernacular geographies across space and time in Flickr and Geograph (geograph.org.uk/) photographs (Dykes, Purves, Edwardes, & Wood, 2008; Hollenstein & Purves, 2010; Purves et al., 2011), relationships between physical and cyber spaces (Graham & Zook, 2011), individuals' patterns of movement in urban environments (Andrienko & Andrienko, 2011; Jankowski, Andrienko, Andrienko, & Kisilevich, 2010; Kisilevich, Keim, & Rokach, 2010) and how tagged social media can be mined to discern non-experts' approaches to classifying images (Rorissa, 2010) or social trends (Jin, Gallagher, Cao, Luo, & Han, 2010), among others.

A significant thread in the research on GTPs has focused on developing and evaluating measures of tag similarity in order to characterize massive numbers of GTPs (Crandall & Snavely, 2012; Crandall et al., 2009) or to support online tools such as tag recommendation engines, query tools, and visualizations of tag semantics (Moxley, Kleban, & Manjunath, 2008; Wu, Hua, Yu, Ma, & Li, 2008). Indeed, much of the research to date using GTPs has been computational in nature, rather than analytically focused, although some recent examples show considerable promise (e.g. De Choudhury et al., 2010). We suggest that the potential exists to generate a finer understanding of *local* environments through investigation of the spatial, temporal, and semantic qualities of GTPs. Rattenbury and Naaman (2009), for example, demonstrate an innovative approach for distilling place semantics from GTP collections using tag- and spatial-scanning approaches that identify locations where significant concentrations or "bursts" of place-related tags are found.

We approach this dimension of localized characterization of space and place by applying a metric adapted from classical odds ratios, used in ecology and epidemiological studies to measure exposure effect, to search for "tag-space" neighborhoods within an urban environment. We are interested here in exploring whether an ecological approach can help quantify the intrinsic spatial and thematic properties of GTPs and uncover areas of tag similarity. In contrast to much of the other research of this type, we use a multi-resolution approach to GTP aggregation that, we suggest, facilitates exploration of urban patterns and processes that occur across different geographies or "scales" of analysis (e.g. streetscapes, neighborhoods, regions). We believe that this approach has potential to help us to understand, to some degree, the strength and spatial extents of citizens' perceptions, filtering and cognition of urban processes and forms. In this way, we may be able to situate previous GTP research related to spatializing place via space–time patterns in Flickr photos (e.g. Crandall et al., 2009; Kennedy et al., 2007) within a broader context of small scale patterns associated with GTPs. Additionally, large scale studies such as those tracing individuals' movement through urban space from temporal trajectories of GTPs (e.g. De Choudhury et al., 2010; Jankowski et al., 2010) may fit another class of scale-specific processes associated with certain landscapes.

In the following pages, we demonstrate our approach to GTP analysis using data obtained for Vancouver, Canada from the Flickr API. Prior to discussing the methods used, we first describe the study area selected for analysis and provide some context related to spatial and temporal changes to the study area during the study period. We then describe our data processing methods and the building of a final GTP database in detail. Following a description of the data analysis methodology, we provide a series of results examining trends in tagging of GTP across space and using tessellations of varying resolutions. We conclude the paper with a discussion of our key findings and highlight caveats of the current analysis and areas for further research.

2. Methods

In this analysis, we are interested in the joint analysis of space, scale and meaning embedded in GTPs obtained for our study area. Scale is handled in a straightforward manner, by making observations at numerous spatial aggregations and comparing how measures change across scales, as is common in biogeographical and ecological research (e.g. Fortin & Dale, 2005; Turner, Gardner, & O'Neill, 2001). Note that in this context, the term "scale" is used as an indication of the resolution at which space is subdivided such that large scale measurements apply to small geographic areas (e.g. points of interest, streetscapes, etc.), while broad regional trends or processes are referred to as small scale (e.g. city-wide commuting flows). Meaning, in the context of analyzing GTPs, requires measurement of either similarity in tag-space or content-space. Tag-space analysis often encompasses tag co-occurrence measures as previously described and examining how these measures are spatially patterned. Hollenstein and Purves (2010) and Jankowski et al. (2010), for example, mine tag descriptions of Flickr GTPs to explore the spatial extent of city cores based on the spatial concentration of selected place terms and landmark preferences respectively. Content-space analysis involves analysis of the digital content of individual and collections of photographs to summarize their relative similarities along some dimension of comparison. For example, an aspatial content analysis called Flickr Distance represents one way this might be accomplished, through clustering of visual language model summaries of pairs of images with common tags (Wu et al., 2008). However relating GTPs based on geography and image content is problematic because people often photograph objects unrelated to their geographic locations. An alternative GTP repository, such as Geograph, whereby participants are tasked with photographing landscapes for specific grids of a reference map covering all of England, holds promise for supporting geo-content analysis, albeit with a sacrifice in generality and spatial resolution (see Dykes et al., 2008; Purves et al., 2011, for example). The approach taken in this paper to elicit meaning is to examine two properties of GTPs across geographic locations: GTP magnitude and GTP tag similarity. Ultimately we aim to associate measures of these properties with meaningful forms and processes in urban environments.

2.1. Data and study area

Data were obtained from the Flickr API for the years 2001–2012 using a radius search at fixed locations in the City of Vancouver. The City of Vancouver is an urban center of 600,000, with approximately 2.1 million in the greater region of Metro Vancouver. The City of Vancouver proper is a growing urban center with heterogeneous cultural and physical landscapes. The physical constraints on the city – an international border to the south, mountains to the north, and ocean to the west – have dictated rapid cycles of urban redevelopment and densification in and around the urban core. The downtown core is representative of the post-industrial city; a

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