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Putting people in the picture: Combining big location-based social media data and remote sensing imagery for enhanced contextual urban information in Shanghai

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ABSTRACT

Urbanization is a set of interrelated processes; the most visible among them are changes in the built-up environment. We relate those changes to human activity as expressed by online social media messages. This approach might shed light on urban dynamics currently intractable through existing datasets and methodologies. Microwave remote sensing images are used to identify urban built-up areas and changes within those areas in an objective way, while geocoded mobile social media messages deliver valuable information about human activity and the vitality found in those areas. A time-series stack of 36 TerraSAR-X Stripmap images and roughly six million social media messages were processed, classified, and visually and quantitatively analyzed for an experiment in Shanghai. We derived four possible cases of land classification by combining the results of both sources to a single raster layer at a 400 m cell size. Quantifying these cases in a 2-by-2 confusion matrix shows positive and negative matches between built-up areas and social media messages. We see that correlation of positive matches is 72%. A combination of remotely sensed and social media data is a step towards a more granular analysis of urbanization processes than is possible from either data source alone. We put people in the picture of traditional remote sensing analysis.

1. Introduction

Urbanization is observable in developing and developed countries. In today's world, more than half of the Earth's population lives in cities, The United Nations Organization World Population Report shows that >50% of the global population lives in urban areas already (United Nations Population Division, 2011). In China by 2030, one billion people are expected to be living in cities; this is far >50%. In this paper, we will focus on the urbanization process in China; in particular, on the detection of built-up areas and human activity in Shanghai (SH) using Synthetic Aperture Radar (SAR) data and location-based Social Media Messages (SMM), bypassing official data sources entirely, for a more objective understanding of these urbanization processes.

We argue that the combination of SAR remote sensing and location-based social media messages can enhance land classification and interpretation of urban development and human activity patterns. Remote sensing identifies urban built-up areas; social media messages are an indicator of human activity in a given area. We show that it is possible to identify 'high' and 'low' built-up areas as well as human activity patterns from each data set. Overlaying and classifying SAR and SMM results generated four possible classes/cases of land-cover.

We used a stack of TerraSAR-X images collected over Shanghai for our experiment. Microwave remote sensing is an objective (Lillesand, Kiefer, & Chipman, 2015) and deterministic (Woodhouse, 2006) imaging system; recording two images under exactly the same conditions will produce identical images, but variations occur due to system noise. Moreover, sensor selection and parameter settings for an image acquisition, such as spatial resolution or time of recording and interpretation of results are subject to human bias. One image represents a single snapshot of the current situation on the ground. A stack of images over the same area delivers a time series. Each time the satellite passes over an area of interest (AOI), it can be observed from almost the same position, creating a time series of image observations; for TerraSAR-X the repeat cycle is 11 days. Every image, therefore, has almost identical properties and thus is suitable for performing Coherence Change Detection (CCD) to monitor changes on the ground.

Microwave remote sensing is useful for identifying urban built-up areas and changes within these areas. Urban areas have buildings, roads, construction, general infrastructure, and paved ground with steel, glass concrete and stone objects. From a technical perspective, these *high coherence* objects appear to be phase coherent in a SAR

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image pair. Because they usually do not move, these objects are considered stable. We define these as built-up areas.

Human activity, in this study, is represented by SMM with geographical coordinates and timestamps. We define human activity as the existence of social media messages (points) within a given area – a grid cell (raster). To post a message, users must interact with a mobile device that signals its current GPS location back to the social media network. This is, in essence, an indication of human activity from one individual at a geo-location. Collecting millions of messages in a municipal area gives us a more general picture of the human activity patterns across the entire city and variations within; from the center, down to small towns (zhen - 镇) and even smaller units, like the Oriental Sports Center or the Pudong International Airport in Shanghai.

Section 1 starts with a discussion of our motivation and continues with a review of the published research relevant to our study. Section 2 describes the big data sets from remote sensing and social media as well as their retrieval. The methodologies to derive and quantify the built-up area from SAR and the inference of human activity from social media messages are detailed in Section 3. Change detection within urban areas and the patterns of human activity are discussed in Section 4. This section also includes an analysis of the combined classifications of both data sets. In Section 5, we draw conclusions, address the limitations of this research, and outline our future research directions.

1.1. Motivation

The contentious socio-political context must be considered when investigating land use patterns and human activity, especially in China. Given their controversial political or commercial nature, the data documenting urbanization are often not trustworthy, reliable, inaccessible, or in many instances, they are outdated. For example, census data is not available for neighborhoods and the data that is accessible, is irrelevant to an understanding of rapidly changing urban dynamics (Taylor, 2001). The census data for the townships in the Shanghai metropolitan area consists of only 235 points (China Data Center, 2013), which is a rather coarse positional accuracy.

The motivation for this study was a need for an enhanced and timely analysis of urban processes in Chinese cities. Structural change and population dynamics as measured by two seemingly unrelated big data sources can be integrated using visual overlaying techniques and quantified through classification. A geographical analysis is possible since both data sets have the same reference system. These data can augment, or bypass traditional data sources for a reliable and less contentious source of data about Chinese cities and complex urban processes.

Microwave remote sensing is a weather and daylight independent image acquisition system. It can provide time-series image stacks that are particularly suitable for detecting and identifying small and large-scale changes in the built environment. Due to its relative independence from atmospheric distortions, SAR delivers more stable time-series imagery than optical imagery. This capacity to create consistent time-series images irrespective of cloud coverage is a major advantage of SAR imagery when the goal is to detect urban change happening over short time intervals (weeks). SAR is an objective and independent system. Thus, determining a built-up urban footprint or the building density become purely technical questions rather than issues influenced by political or commercial interests. SAR or any other space-borne remote sensing imagery, however, does not provide information about direct human activity. People are not visible or classifiable in an image unless the resolution is very high or taken from an air-borne sensor.

Social media messages are a readily available and timely means to quantify and measure human activity particularly A point cloud, gathered from a location-based social media network is one possible data source useful for discerning human activity in a small area. This social media activity might or might not be directly linked to changes in the built-up environment.

The development of built-up spaces and human activity are not always congruent and simultaneous. This leaves uncertainties when only looking at remote sensing data that can be used to classify an area as urban by just looking at built-up structures ignoring the fact that something becomes urban with the presence of people. Patterns arise that are concurrent, shifted in time or never overlapping as shown in Table 1. Example: An area can have a high degree of urbanization on the structural level, but people are not living there leaving the environment in a state similar to a 'ghost town'.

Social media messages give us a representation or albeit a limited, picture of human activity occurring on the ground and can augment the view from satellite cameras or remote sensing devices. Social media is partial and limited, leaving large areas of uncertainty. We are restricted to people from a society with a strong technological orientation who also use Sina Weibo on a mobile device with the reception of location information. This allows us to capture human activity at any time of the day for a single individual. We are focused on human activities as measured by messages on social media per area unit, not in the exact number of people per area unit. The issue we address are urban processes occurring at two scales, change occurring in the larger built environment and the activity patterns represented by aggregated SMM from individuals.

1.2. Literature review

This study is a contribution and a tool for urban planners and designers as well as scientists dealing with spatial information from various sources to observe urban processes. The literature that has been reviewed comes from two major fields of research: a) urbanization as seen from space (remote sensing) and b) urban processes such as human activity (inferred from social media). An approach that fuses both research fields directly was published in Liu et al. (2015). The author describes the similarities of representation and analysis of remote sensing imagery and data gathered from human activity (taxi trajectories and check-in data from social media) and calls this type of research social sensing.

1.2.1. Remote sensing

Remote sensing plays an important role in China's urban planning process (Esch, Taubenbock, Felbier, Heldens, Wiesner & Dech, 2012; Xiao & Zhan, 2009). There have been studies on the subject of urban change using satellite data from microwave sensors (Liu & Yamazaki, 2011) to detect urban changes using amplitude (Boldt & Schulz, 2012)

Table 1
Basic schema for visual classification: Density of built-up and density of social media messages lead to four possible cases.

Social Media Messages \ Built-up area	high	low
high	Case 1: e.g. CBD	Case 2: e.g. a park
low	Case 3: e.g. industrial area	Case 4: e.g. agricultural land