[DC-02-011] Street-level Imagery

Abstract

Street-level imagery consists of collections of photographs taken from the perspective of moving pedestrians or vehicles. These collections are often stitched together digitally and georeferenced to create interactive and immersive landscapes that are virtually navigable by users. Such landscapes, sometimes called 360-degree panoramas, or bubbles, are uploaded onto web platforms, and linked with geographical databases, which allows users to search and explore the imagery in various ways. IT companies such as Google have created street-level imagery platforms that rely primarily on paid drivers, although they have begun to rely on contributor submissions to complement and expand their coverage. Recently services such as Mapillary and OpenStreetCam have advanced a model that relies primarily on volunteer contributors, leveraging community interest from projects such as OpenStreetMap. While street-level imagery has become a widespread tool with multiple commercial and non-commercial applications, it is also entangled various legal and public opinion controversies, due to its capabilities for private data collection and surveillance.

Keywords: crowdsourcing, Google Street View, ground imagery, navigation systems, street view, street-level imagery, VGI, web maps

Author & citation

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Explanation

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1. Definitions

- **Street-level imagery**: Collections of photographs taken from the perspective of pedestrians or moving vehicles, which are often stitched together digitally and

georeferenced to create interactive landscapes that are virtually navigable by users.
- **Augmented reality**: The integration of a variety of layers of digital information with geolocated media, which can enhance or augment the experience of particular places in contingent, often highly-personalized ways.
- **Mashups**: Combinations of different media or services by users to create new products.
- **Crowdsourcing**: Relying on contributions from a large pool of Internet-based volunteers in order to build an extensive digital product or accomplish a big task

2. Introduction

In its simplest form, street-level imagery consists of collections of photographs taken from the perspective of moving pedestrians or vehicles. These collections are often stitched together digitally and georeferenced to create interactive and immersive landscapes that are virtually navigable by users. Such landscapes, sometimes called 360-degree panoramas, or bubbles, are uploaded onto web platforms, and linked with geographical databases, which allows users to search and explore the imagery in various ways —such as text searches, dragging motions, or point-and-click functions. The integration of street-level imagery into web maps and other (spatial and non-spatial) databases in turn enables users to surf between street-level photographs, maps, and other place-specific information–such as user-generated reviews, or social media content. Street-level imagery also aids analysts and cartographers with confirming objects viewed in areal or satellite imagery, while providing a way to virtually explore and research environments that might be otherwise difficult to access due to cost, distance, or time limitations.

By 2019, after nearly a decade and a half of its appearance, street-level imagery has become a commonplace technology in large part due to its incorporation into search engines, Web 2.0 maps, and connected services, something that has been advanced with great success particularly by Google. Both in terms of imagery and number of users, Google Street View, the company's street-level imagery platform, has achieved remarkable coverage throughout the world. However, while this platform is possibly the most well known of its kind (aided by the popularity of Google's other linked services, such as Google Maps and Google Search), the array of alternative services speaks to street-level imagery's developmental history, growing applications, and evolving ramifications.

While Google Street-View has revolutionized street-level imagery, the idea behind this technology has had several incarnations over the decades. Stretching as far back as the late 19th and early 20th Centuries, there are technological precedents to street-level imagery technology, such as the Cyclorama (round rooms with landscapes painted on the walls), early street-scene film footage (such as the Miles Brothers's 1906 film 'A Trip Down Market Street'), and the photo-auto maps that became popular with the emergence of automobiles. However, a more direct antecedent is the Aspen Movie Map, developed in the late 1970s by researchers at MIT. This map combined street footage with digital maps, and even touch screen displays to provide the user with an interactive experience of a place —in this case Aspen, Colorado—, which was often referred to as 'surrogate travel'. It was this concept that motivated the creation of the Aspen Movie Map, as well as its funding, since it was developed with Department of Defense support via DARPA as a way to train soldiers for unfamiliar environments (Weber, 2014).

Decades after these pioneering ventures, street-level imagery as we know it today emerged in the mid-2000s with a series of experimental initiatives from established IT companies. It later spread through user-enhanced mashups that took advantage of new data storage capabilities, smooth and asynchronous HTML and JavaScript-based web navigation, and the ability to connect and combine various types of web services and maps. Amazon launched Block View in 2005, which provided storefront information linked to the company's Yellow Pages partner service. In 2006 Microsoft released Streetside, which provided an interactive feature where the users could move down the street and view the landscape through a car's windshield (Fisher, 2013). This allowed users to simulate driving a car through street grids and looking through the windshield. However, the interface and the navigation were rudimentary, and its applications were not immediately apparent. Google Street View, which was born out of a Google experimental project, appeared in 2007 and improved on existing street-level imagery platforms, almost immediately surpassing user traffic expectations (Olanoff, 2013). This success was a result of a number of factors, such as combining technical innovation with user experience, connection to Google Maps, and the ability for users to embed the images in new products and services through the use of an Application Programming Interface (API).

Although Google Street View has set a standard for street-level imagery and remains the market leader, a notable area of recent growth is with platforms that crowdsource the acquisition of street-level imagery. While Google Street View has recently begun to add crowdsourced imagery to complement its coverage, by their nature and operations, majority-crowdsourced initiatives such as OpenStreetCam and Mapillary constitute a qualitatively different approach to the production, use, and circulation of street-level imagery.

In spite of the proliferation of new types of street-level imagery platforms, this medium continues to rely on a core characteristic: the digitalization and georeferencing of the landscape —a visual and pictorial genre that goes back centuries and spans a wide range of media— as a basis for the creation of a virtual environment that is both navigable and expandable. Navigation is a key feature because it allows users to experience a simulated movement through the landscape, and enhance this experience with information about elements of the landscape, such as street names, business addresses, and myriad other tags —a form of geospatial media that can be understood as 'augmented reality' (Graham, Zook, & Boulton, 2013).

The enhancement of landscapes, along with the ability to zoom, pan, and hyperlink to related documents or media constitutes an expansion of the virtual environment that makes street-level imagery distinct from other forms of geospatial media. Finally, street-level imagery also provides a level of immediateness, access, and verisimilitude that creates a sense of 'being there'. It is these immersive qualities that have brought street-level imagery under the microscope due to its potential for systematic invasions of privacy and far-reaching surveillance capabilities. The next sections explore the different types of street-level imagery platforms that have emerged, as well as the possibilities they create and the various implications of this technology.

3. Platforms Relying Primarily on Paid Drivers

While Google Street View —and to a lesser degree other corporate platforms—have succeeded in achieving widespread coverage, this has come with large fixed costs in labor, equipment, and maintenance. The high price tag that comes with producing and maintaining a street-level imagery platform is a result of the scale and logistical complexity of this endeavor: outfitting specialized vehicles equipped with customized cameras to traverse and photograph entire street-grids or vast roadway systems.

Large companies associated with Internet search and commerce have so far been the most willing to expend the capital required to amass collections of street-level imagery. This is done primarily by relying on their own fleet of vehicles driven by hired drivers, although other kinds of vehicles and backpacks have been used. Notable platforms at the time of this writing include Google Street View, Microsoft Streetside, Yandex.Maps Panoramas, and Baidu Total View. The imagery is collected in vast, systematic chunks and then processed in house using proprietary methods.

With paid drivers, geographic patterns of collection largely correspond to the business needs and priorities of the corporation, although some areas may remain empty due to legal restrictions or censorship. Safety concerns and physical barriers also appear to play into coverage decisions (Quinn and Alvarez León 2019). Google Street View has collected rural and urban coverage throughout the world, although in many lower income and politically restrictive countries there has been little or no attempt to gather imagery. Microsoft’s Streetside covers parts of the United States and Western Europe. Yandex.Maps Panoramas cover selected urban areas in Eastern Europe, Turkey, Armenia, and many parts of Russia. Baidu Total View imagery is available in Chinese urban areas.

Each of these platforms maintains a website where users can navigate an interactive map and view coverage patterns via a web browser. Some platforms such as Yandex.Maps Panoramas permit the user to toggle between several timestamps, revealing how the streetscape has changed over the years. Each platform offers an API allowing developers to reference a location and embed the street level imagery into existing websites and apps through code. The terms of use and pricing are different between platforms, but follow basic models of associating the app with a developer key and tracking the number of views.

As a way to complement and extend its coverage, Google has developed a secondary model of street-level imagery collection for Google Street View. This can be seen through the establishment of programs that recruit Street View users to become contributors by attaining ‘Trusted Pro’ or ‘Local Guide’ status, which lends an official imprimatur to the imagery and data they submit to the platform. Programs like these allow Google to draw from user-generated data and extend Street View’s coverage in places where the company does not have an official presence, such as China and India. While this is not the main part of Google’s model, it is important to consider the rise of crowdsourced work, since it is gaining traction not only as a complement to traditional paid coverage, but also because it is fueling the appearance of companies with alternative data collection strategies.

4. Platforms Relying Primarily on Crowdsourcing

Some street level imagery providers who don’t require 360-degree panoramas or comprehensive coverage have chosen to base their activities primarily on crowdsourced imagery contributed by volunteers with ordinary smartphones. This allows them to avoid

the upfront cost of managing an imagery-gathering fleet. Mapillary and Telenav's OpenStreetCam are two such alternatives, which have built their data collection models on the same kind of crowdsourcing dynamics that have enabled large-scale informational projects such as Wikipedia.

Volunteer contributors to Mapillary and OpenStreetCam typically collect images with a smartphone app that takes pictures at a regular interval. The phone or other camera-enabled device is usually mounted on the dashboard when operating a personal vehicle. The contributor then uploads the images to Mapillary and OpenStreetCam's servers, where they are used as inputs to commercial products and services, such as text and feature extraction from images, as well as navigational services.

The geographical extents of imagery coverage obtained by the crowdsourced services are often less comprehensive than those obtained by paid drivers; although they extend into a wider variety of countries. As Google has found through its Local Guides, launching crowdsourced imagery collection in a new country requires less upfront cost and is more discreet than a systematic data collection campaign using a vehicle fleet.

In some places, both Mapillary and OpenStreetCam have extended their coverage for focused projects using paid drivers collecting imagery across targeted zones. Third-party companies collecting imagery have also sometimes shared their data with these platforms, resulting in a coverage map where systematic patterns are blended with the personalized and less-predictable geographies of the volunteer contributors (Quinn and Alvarez León 2019).

Mapillary and OpenStreetCam allow contributors to browse individual images, while at the same time retaining an extensive bundle of rights over the images. Mass downloads are prohibited. Both Mapillary and Telenav also allow people to use the images as a ground truthing mechanism to improve OpenStreetMap (OSM), a crowdsourced and not-for-profit geographic database built by hundreds of thousands of contributors worldwide. In a symbiotic relationship, these crowdsourced street-level imagery platforms draw heavily from the OSM community to recruit contributors (Alvarez Leon & Quinn, 2019). Yet, OSM mapping is very different from collecting street-level imagery. While all that is needed to improve OSM is knowledge of an area, a computer, and time to edit the tracks, the individual costs and requirements to collect street-level imagery are much higher. Contributors need to physically move through space (most often driving) and continuously take photographs using a digital camera. This often implies the need for data storage, the risk of overheating phones, the demand for vehicle fuel and maintenance, and the time required to take, edit, and upload the images.

5. Impacts and Implications of Street-Level Imagery

The convergence of advances in high-speed computing, crowdsourcing, digital mapping, and web searching have made street-level imagery a household technology with applications that range from wayfinding to tourism and research. However, beyond the experience of users, street-level imagery has gained prominence as a way to localize advertising and enhance other online services such as real estate websites. All of this points to the widening economic and cultural ramifications of a technology that was in experimental stages a decade and a half ago. However, both the longer history of street-

level imagery and its ongoing developments signal some of its larger implications as it is entangled with issues about privacy, politics, and security, among others.

As with the Aspen Movie Map, which was developed to enhance 'surrogate travel' for soldiers through Department of Defense funding, it is worth considering the various military and (geo)political implications of collecting high resolution imagery of landscapes throughout the world. It is therefore no accident that various governments and their populations have reacted very strongly to the collection of this type of data –particularly in the case of Google Street View. From popular resistance in Germany and the UK on the grounds of personal privacy to temporary bans in Greece (Geissler, 2012), to an international scandal due to the collection of wifi data in the course of Google car navigation (Burdon & McKillop, 2013), to the blanket prohibition of the platform in India due to the suspected role of street-level imagery in planning terrorist attacks (PTI, 2016), the broader implications of who collects, owns, and controls access to potentially sensitive imagery have colored the development and uptake of this technology. This has been accentuated by the recent incorporation of features to extract additional information from images, which can range from street signs and store fronts to, more controversially, facial recognition.

With all of these considerations in mind, it is thus important to evaluate street-level imagery as a very powerful tool that has the potential to shape how we perceive, navigate, and act upon the world. This means that claims of representing 'the world as is', in the words of Luc Vincent, Google Street View pioneer (Weber, 2014), should be questioned and qualified with analyses that take into account the various power dynamics at play in the collection, interpretation, distribution, ownership, and control of the imagery. As more features and technology become integrated into street-level imagery, and this service becomes increasingly popular, these questions are likely to become more important, as this is already one of the windows into our world that mediate the experience of millions of people, which in turn represents an important revenue stream (and locus of power) for an expanding array of firms, governments, and other actors.

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