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Google Maps as Cartographic Infrastructure: From Participatory Mapmaking to Database Maintenance

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Google Maps has popularized a model of cartography as platform, in which digital traces are collected through participation, crowdsourcing, or user's data harvesting and used to constantly improve its mapping service. Based on this capacity, Google Maps has now attained a scale, reach, and social role similar to the existing infrastructures that typically organize cartographic knowledge in society. After describing Google Maps as a configuration relying on characteristics from both platforms and infrastructures, this article investigates what this hybrid configuration means for public participation to spatial knowledge in society. First, this turn to infrastructure for Google has consequences on the status of public participation to mapmaking, which switches from creating content to providing activities of maintenance of its database. Second, if Google Maps "opens up" cartography to participation, it simultaneously recentralizes this participatory knowledge to serve its corporate interests. In this hybrid configuration, cartographic knowledge is therefore simultaneously more participatory and more enclosed.

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Keywords: algorithms, API, crowdsourcing, digital cartography, Google Maps, knowledge infrastructure, maintenance, participation, platform, Web mapping

Cartographic information is traditionally organized by an ecosystem of actors that provides the technologies and expertise to create, maintain, and disseminate spatial knowledge in society. It comprises national geographic institutes (such as the UK Ordnance Survey or the French IGN), responsible for the authoritative representation of a national territory; geospatial imagery companies, which possess satellites to acquire images and software to analyze geographic data; technologies, such as GIS, which act as standard to communicate and work on geographic information; universities and education programs, responsible for teaching and disseminating cartographic knowledge, whether through the manipulation of specific software or more generally through spatial and cartographic literacy. Together all these actors constitute for cartography what has been called a *knowledge infrastructure*, defined as “robust internetworks of people, artifacts, and institutions which generate, share, and maintain specific knowledge about the human and natural worlds” (Edwards et al., 2013, p. 23). Seen through this lens, cartography constitutes an essential service in society, aiming for the exhaustive coverage of a specific territory[2] and to provide wide accessibility for cartographic information to the public[3]. Reliability is another key property of knowledge infrastructure (Edwards et al., 2007), achieved through constant updating of maps, and is related to long-term sustainability of mapping, by making sure that maps are properly archived and available for future generations.

[2] State security interests are a traditional limitation of this goal, as critical facilities and administration buildings are regularly removed from maps.

[3] This does not mean that accessing base maps from mapping institutions is free (in fact, it rarely is), but that access does not depend on the “users’ identity or intended use” (Frischmann, 2012, p. 7).

This infrastructure remains a structuring force for geographic knowledge in society. However, the rise of the Web has promoted an alternative configuration for mapping: cartography as *platform*, as illustrated by the project Google Maps or OpenStreetMap, both started in the mid 2000's. Cartography adopts here properties from Web-based platforms, such as programmability and modularity (Helmond, 2015; Montfort & Bogost, 2009; van Dijck & Poell, 2013), but most importantly, openness to multiple forms of participation from non-cartographers and non-geographers (Goodchild, 2007; Haklay et al., 2008; Plantin, 2015; Sui, 2008). In this configuration, maps can be much more easily modified, reused, and remixed by users. It also means that the plurality of digital traces that users of mapping platforms leave—either as active contributions to a base map (e.g., by editing a street name or a road), or as indirect production of data (e.g., by generating data on traffic by using a mapping service or GPS) —are used to create, update, and refine a geographic database.

By analyzing the genealogy and the current architecture of Google Maps, this article argues that this quintessential mapping platform has now attained a scale, reach, and social role similar to existing knowledge infrastructures. It does not mean that Google is replacing the existing infrastructure for cartography—in fact, it strongly relies on several of its components, such as standards and base maps—but rather that it constitutes a mapping platform that has reached a scale and social status that was previously only attained by knowledge infrastructures. What is specific to Google is that it reaches such status by leveraging on properties of the two configurations (Plantin et al., 2016), hereby constituting a hybrid entity. On one hand, Google Maps is a platform, inasmuch as it relies on the programmability of its content and on the multiple forms of participation from users; on the other hand, by being the most widely used mapping service and by powering numerous everyday third-party applications, Google Maps provides a service without which contemporary societies could hardly function anymore, similar to infrastructures (Edwards, 2003).

Such hybrid configuration interrogates how infrastructures and platforms shape how knowledge is produced, disseminated, and accessed in a digital age. By combining the strengths of both private platforms and authoritative knowledge infrastructures, Google is in a de facto position of power to “produc[e] and certif[y] knowledge” (Gillespie, 2014): It can decide what needs to be included or excluded from the cartographic representation, who determines society’s spatial representation, and what form and shape public participation will take. This article investigates the consequences on public participation to cartographic knowledge when Google Maps has such power. First, the status for the public participation to mapmaking changes in this hybrid configuration, from content creation to activities of maintenance. If the main outcome of the platformization of cartography in the mid 2000’s has been to “open up” the map to multiple forms of participation, Google Maps combines this openness with needs that are specific to infrastructures. As Google Maps grows to the level of infrastructure, it is confronted with infrastructural problems, that is, guaranteeing the constant updating and accuracy of its map: It addresses these problems by channeling public participation to accomplish such tasks of maintenance. Participating to Google Maps therefore does not consist anymore of simply adding content, but also of maintaining its geographic database. Second, the corporate nature of Google Maps results in an enclosure of the inputs coming from this participation. Google Maps combines a process of decentralization (by opening its base map to public participation) with a process of recentralization (around its market interests), typical of platforms (Helmond, 2015). The model of cartography promoted by Google Maps is therefore further expanding the role of public participation to mapmaking, while simultaneously concentrating the results of this participation to gain a leading position in the highly competitive sector of the geospatial Web. With projects such as Google Maps, cartographic knowledge is therefore more participatory, but simultaneously more enclosed.

To reach these two results, this article relies on a framework that grasps the complex nature of such hybrid configuration. It combines *infrastructure studies* with *platform studies* (Plantin et al., 2016), two fields of investigation traditionally separated (the first originating from Science, Technology, and Society and Information Sciences, the second living mostly in Media & Communications or Management studies). The first perspective reveals cartography as an essential knowledge in society (Edwards, 2010) and highlights its relational nature (Star & Ruhleder, 1996), that is, the labor and maintenance (Bowker & Star, 1999; Downey, 2014) necessary to create and update Google Maps. The second perspective emphasizes the role Google Maps increasingly plays as a platform that shapes public discourse (Gillespie, 2010), engages in datafication of social life (van Dijck, 2014) and shapes communication following an economic logic (Langlois & Elmer, 2013). Combined together, these two frameworks highlight what is at stake for spatial knowledge in society when mapping platforms compete with existing knowledge infrastructures.

Google Maps: Between Platforms and Infrastructures

In this first part, I describe that Google Maps is *more than just* a mapping platform, as it is now actively producing geographic data and maps, as opposed to only connecting producers and users of geographic data; but it is also *almost* a knowledge infrastructure, as it adopts their scale, without taking all the responsibilities in terms of accountability or accessibility.

Let us start by considering the evolution of cartographic data sources used by Google Maps since its release:

In 2005, Google launches its *Google Maps* website, which aggregates base maps from a multiplicity of public and private sources (e.g., TIGER data from the US Census Bureau or mapping companies such as Teleatlas or Navteq);

In 2007, Google launches the project *Google Street View* and starts collecting panoramic views of streets mostly by using cars, first in the US, then in multiple locations around the world;

In 2008, the Google project *Ground Truth* is launched at the mapping division of Google to aggregate maps from authoritative sources, social media reports, but most originally, on image-processing algorithms that extract street names or traffic signs from Google Street View images to update the Google Maps database;

The same year, Google releases the project *MapMaker*, allowing users to suggest modification of roads, street names, points of interests, etc., using an edit mode popularized by the participatory mapping project OpenStreetMap;

In 2009, Google launches the project *reCAPTCHA*[4] to “crowdsource” the transcription of images from its various scanning projects, among them Google Street View;

In 2013, Google acquires *Waze*, a participatory GPS service, accessing and displaying real-time information from users about traffic on Google Maps;

In 2014, Google acquires *Skybox Imaging*, and now operates Earth observation satellite imagery.

This account of the ways Google creates its map is by no means exhaustive, and each of these complex processes would require more elaboration; additionally, the way Google envisions and builds its map is very much an evolving process. However, it is possible to extract two key elements from this chronology that characterizes the current strategic role digital traces play in the Google Maps project. First, mapmaking according

[4] Originally developed at Carnegie Mellon University and later acquired by Google in 2009 (and renamed ReCAPTCHA), the CAPTCHA technology is an automated Turing test that asks website visitors to show they are human by transcribing two series of texts in natural language.

to Google results from the combination of human and computational processes, both at the level of data collection and data processing: Google relies on map users' participation through their reporting of problems and mistakes, or their transcription of relevant information into natural language (such as a house number from a Google Street View image); these data inputs are then processed by algorithms that compute large quantities of data. Second, Google is increasingly putting effort into building its own mapping capacities. While Google creates and updates its mapping service by aggregating several existing public or private sources, it now also combines several internal services owned by Google (e.g., images from Google Street View provide data to update Google Maps) and has been building its sovereign mapping capacities (in terms of technologies for spatial data processing, but also in terms of satellites for mapmaking).

The combination of, on one hand, this reliance on human and computational means with, on the other hand, an increasing move towards independence of its geographic data provision, results in a hybrid mapping project: Google Maps relies on participatory processes that are typical of Web 2.0 and Web-based platforms, but it has also reached the technical capacities and the level of use typical of cartographic knowledge infrastructure. In this first part, I describe how Google leverages the properties of these two configurations, and later how this hybrid nature of maps has consequences for public participation and knowledge in society.

Making Cartography "Platform-Ready"

A few months after Google released its Google Maps service in February 2005, it released its Google Maps API (Application Programming Interface, in June 2005), which offered a technical and legal framework allowing third parties to access, display, and customize a base map. This combination of bottom-up and top-down innovations introduced digital cartography into the world of Web-based platforms and triggered a trend of mashups (Sonvilla-Weiss, 2010) using a cartographic layer. Through Google Maps, mapping practices meet participatory culture: "In geographic terms, participatory culture is what happens when you throw Google Earth out there and people start doing their digital overlays on it, in totally unanticipated projects" (Jenkins, 2009). A diversity of terms similarly emerged in the mid-2000's in geography to account for this new role of users, not constrained to the reception side anymore, but taking a more active role in creating maps: "Neogeography" (Turner, 2006) (Graham, 2010), "Volunteered Geographic Information" (Goodchild, 2007), "Webmapping 2.0" (Haklay et al., 2008), and "Wikification of the map" (Sui, 2008) are examples of such terms. Across media studies and geography, the emphasis on participation shows the deeper role users play in creating and using maps, as well as the extension of mapmaking to non-geographers and non-experts in cartography (Plantin, 2015). Creating and manipulating an online mapping application after Google has therefore less to do with traditional GIS properties (Turner, 2006), but is closer to other digital media practices (Farman, 2010).

In addition to participation, programmability and modularity are the other two defining properties of platforms applied here to Web-based maps. Programmability means that content is made accessible in a structured format that allows users to develop applications from third parties (Montfort & Bogost, 2009; van Dijck & Poell, 2013). Modularity characterizes the architecture that allows such programmability. It defines the articulation between the three components that constitute a platform: a core component with low variability, complementary components with high variability, and interfaces for modularity between core and complementary components (Baldwin & Woodward, 2008). In the case of maps, it means that Google Maps makes cartographic information programmable by organizing the modularity between a core component (a base map) and complementary components (such as online mash-ups or mobile applications created by third parties) through an application programming interface.

Participation, programmability, modularity: by adopting such characteristics of digital platforms and applying them to digital cartography, Google Maps has made maps 'platform-ready' (Helmond, 2015): the strategic use of APIs reconfigured map manipulation and spatial data input to fit with existing Web-based practices. However, I show below how this configuration is increasingly combined with properties traditionally associated with infrastructures.

Webmaps as Knowledge Infrastructure

Google certainly relies massively on the existing cartographic knowledge infrastructure in order to create its own mapping service. Google uses existing base maps from public institutions to feed its maps; it relies on technologies and standards (from satellite to GPS) to collect geographic data; it hires engineers who acquired their expertise in universities, etc. In that sense, Google Maps would clearly not have been possible without the existing knowledge infrastructure that provides the basis to start its mapping project.

However, the Google Maps project taken as a whole (that is, encompassing all data sources Google mobilized to create and update its maps, mentioned earlier) has recently been adopting properties that have long been associated with infrastructures. This configuration meets an increasing interest in describing digital media through the lens of their infrastructural properties (Parks & Starosielski, 2015), either to emphasize the materiality of communication over content—for example by showing how Internet cable networks (Starosielski, 2015) or data centres (Hu, 2015) organize computer-mediated communication—or to highlight the values embedded in infrastructure when they organize the circulation of information and knowledge in society (Peters, 2015). This perspective is useful to investigate the increasingly infrastructural nature of Google Maps, as well as how it relates to and differs from existing institutions dedicated to cartography.

What makes Google Maps closer to a knowledge infrastructure? Google Maps is free to use and accessible for anyone having a mobile phone or a Web browser. Its use is part of a learned membership. It has reached a global scale, as it goes beyond the traditional national mandates of mapping institutions, with 1 billion active users of the

Google Maps website worldwide.[5] The Google Maps API is used to power numerous applications to the point of constituting a de facto standard for online map. It is reliable and mostly invisible, yet a breakdown of Google Maps would disrupt all the services that depend on it—including business, government, work, and everyday commuting.

Google therefore constitutes a specific actor in the existing spatial knowledge infrastructure, as it posits maps as a combined process of platforms and infrastructures (Plantin et al., 2016): on one hand, the Google Maps project transformed the map into a Web-based platform by relying on crowdsourcing to keep the maps updated and on APIs to guarantee massive reuse of its maps in browsers or mobile applications; but on the other hand, Google Maps is also increasingly "infrastructuralized," as it is now reaching the scale and social utility that is typical of knowledge infrastructures. However, it still differs from the traditional definition of infrastructure, as it remains profit-driven and is not subject oversight to maintain public interest; its standardization is also unilaterally imposed, and does not result from regulation.

Digital Platforms and Splintering Infrastructures

The rise of such mapping project does not only result from the computing power of Google. More specifically, it emerges from two changes in the landscape of geospatial information: first, the rise of digital cartography, that started already with GIS technologies, which shed light on traditionally opaque cartographic processes; and second, the splintering of dedicated cartographic institutions, leaving room for other actors to rise and take up a stronger role in mapmaking.

Critical literature in cartography has highlighted how cartography is intrinsically embedded within power relations: power "traverses" the way maps are made and used

[5] Popular Science, 'Google has 7 products with 1 billion users', February 1, 2016: http://www.popsci.com/google-has-7-products-with-1-billion-users

(Harley, 1989). They are intrinsically related to the rise of nation states (Wood, 2010); in their digital form, they derive their power from the assumptions of objectivity they create (Pickles, 1995). For all these reasons, the creation and the circulation of cartographic knowledge are a matter of control over who is mapping, who is mapped, and who can access the map. Affirming that the rise of computer-based cartography, appearing as early as the late 1960s (Coppock & Rhind, 1991) or of Web-based mapping, as early as 1993 (Haklay et al., 2008) automatically renegotiates this plurality of forms of power would be far too easy. However, what is different with digital cartography is that the steps of production for a map are less easy to conceal or to forget: users are constantly reminded of the materiality of all the elements and processes that are aggregated together to create the final product of the map:

> If you could easily forget the masses of institutions, skills, conventions and instruments that went into the making of a beautifully printed atlas, it is much more difficult to do so now that we are constantly reminded of the number of satellites presiding over our GPS, of the sudden disappearance of network coverage, of the variations in data quality, of the irruption of censorship, of the inputs of final users in sending data back, etc. (November et al., 2010, p. 5)

If it has always been possible to see surveyors in the field, OpenStreetMap has pushed this visibility over the cartographic process the furthest: it made salient the different steps that constitute maps, from data collection to editing to online publication. It does not mean that everyone can become a cartographer without the necessary skills, but rather that cartography appears less like an opaque process. What digital maps and Web-based participatory modes of cartography therefore brought is a *depunctualization* (Callon, 1984; Gehl, 2016) of mapmaking: all the different actors, technologies, and processes that are necessary to create a map are made visible (or at least, less concealed) and revealed through participation to mapmaking. This visibility gained over the multiple steps that constitute mapmaking makes it easier for new actors that are not typically related to cartography (but who possess the necessary expertise and technical resources) to produce maps.

The depunctualisation of maps that comes with its digitization needs to be considered in coordination with a second factor: multiple mapping platforms can more easily emerge at a time of “splintering” of existing infrastructures. Graham and Marvin (2001) use that term to describe the state of urban infrastructures as increasingly retrofitted and replaced by “networked premium spaces” that guarantee benefit of access to selected users, as opposed to the “modern infrastructure ideal” that bears the promise (albeit always unequally realized) of general service and accessibility for all. Applied to cartographic institutions, the rise of the geoweb, with Web mapping platforms at the forefront, takes place in this context of splintered cartographic institutions. The geoweb increases a “roll back” of the state from its traditional role as authoritative source, which is followed by a “roll out” (Leszczynski, 2012) of various mapping actors, not-for-profit and for-profit, that all have more freedom to develop their own mapping capacities.

This movement of roll back/roll out does not mean that private mapping platforms such as Google Maps and others are simply replacing dedicated cartographic institutions. Rather, online platforms alongside national mapping institutes appear as one possible configuration among multiple sources of cartographic data, as Leszczynski puts it:

> In the West (the USA and UK in particular), rather, the state’s role is changing from that of sole purveyor of geographic information and arbiter of cartographic truth to that of one of many producers and facilitator or institutional body of oversight.” (Leszczynski, 2012, p. 78)

Cartographic knowledge infrastructures are therefore not disappearing; they simply do not create the only obligatory passage point to create, validate, and disseminate maps. The rise of new material forms for creating and publishing mapping data, based on participation and openness, accompany the end of the ‘modernist era of mapping’

(Goodchild, 2009) characterized by the state as the central authority for creating and disseminating maps as official knowledge. What results is a map that has lost its “ontological security” (Kitchin & Dodge, 2007), as there is not only one single legitimate way of mapmaking that is backed by technical expertise and political power.

I have so far characterized Google Maps as a twofold entity: as a platform, this service “opens up” cartography by expanding the categories of actors that can create and use maps, while simultaneously wresting control over maps from the monopoly of traditional cartographic institutes; but it has now reached a scale that makes it compete with the knowledge infrastructures that traditionally organize cartographic knowledge in society. Combining the participation, programmability, and modularity of platforms with the scale, reliability, and essential nature of infrastructures, Google therefore plays an important part in “producing and certifying knowledge” (Gillespie, 2014), by deciding what and who is included or excluded from cartographic representation. This move from authoritative knowledge infrastructures to privatized platforms is reshaping the politics of knowledge itself, and asks the fundamental question of who participates in a society’s spatial representation, and how.

For the remainder of this article, I move from using infrastructures and platforms as objects to using them as concepts. Each of these two objects has been at the center of dedicated fields of inquiry—respectively and chronologically infrastructure studies and platform studies—that I describe below. More precisely, I select amongst these two large bodies of scholarship authors that have specifically operated a critical investigation of how infrastructures or platforms shape knowledge in society. These two perspectives, typically separated, are put here into a dialogue that allows us to interrogate the role Google Maps takes in the creation and dissemination of an essential knowledge in society.

Participating in Google Maps: From Content Creation to Maintenance

One of the defining traits of cartography (in digital or non-digital form) is that the effort needed to update the base map never ends, as the territory that the map represents is constantly changing e.g., in terms of borders, toponyms, or occupation of space (buildings, roads, etc.). As Google Maps entered the geospatial sector by following the logic of platforms, it relied almost exclusively on other mapping services to display cartographic content, and it could therefore rely on them to make sure the accuracy and updating of maps was guaranteed. However, now that it is moving towards creating its own mapping capacities, it needs to find by itself the means to tackle this problem of accuracy and updating. As it constitutes a hybrid entity mixing properties from two configurations, it does not have to rely on ways of maintaining maps that are typical of mapping infrastructures (e.g., surveyors in the field): Instead, Google Maps applies the characteristics of digital platforms to perform this task, particularly by channeling users' participation.

Aggregating Multiple Data Sources to Update Maps

What are the forms that participation takes in Google Maps? First, it allows users to suggest changes and modification of the map through the "edit mode" of the Google Maps website or mobile application. These edits are then moderated by hired Google operators and included if relevant (Kelion, 2012) It is the form of participation that is the closest to the "Web mapping 2.0" (Haklay et al., 2008) ethos in which users can contribute directly to the map.

Second, this type of participation is complemented by an automatic collection of digital traces generated by users of Google Maps mobile applications. Such reliance on users equates transforming every user's mobile into a sensor[7] that provides real time

[7] UK Business Insider 'The 2 simple reasons why Google Maps is better than everything else.' November 25 2015: http://uk.businessinsider.com/the-reason-google-maps-is-the-best-traffic-app-2015-11?r=US&IR=T

information on the state of traffic, but which also provides usable data to update its map. For example, simply by driving, Google Maps users provide navigational data that confirm to Google that this road actually exists, or that the map displays the accurate direction for driving.

Third, the Google mapping division relies on crowdsourcing to organize the modularity of spatial data between Google Street View and Google Maps. In addition to providing a large amount of images, Google Street View also provides a great quantity of data relevant to update its maps: traffic signs, intersection, names of shops and streets, sense of direction for driving, presence of a new building, etc. Once collected by the Google cars and other devices, such "real world" information is extracted from Google Street View images and then compared with Google Maps to verify that the same information is accurate and updated on Google Maps. Through the constant provision of "real-world" data, the imagery service therefore provides Google Maps with a "ground truth" to verify the accuracy of its map. This work is achieved through what the Google engineers call "algorithms and elbow grease." For the algorithmic part, it consists of a process similar to optical character recognition (OCR [8] to delineate and extract information on the images collected (e.g., street names) that are of interests to update the map.

However, and this is crucial to understand the role of users participation in Google Maps, the passage between data from Google Street View to Google Maps is not automatic, nor does it occur without glitches. The large-scale digitization and processing of real-world image relies on dedicated work that aims to adjust and compensate for the limitations of algorithms. This is where the "elbow grease" factor comes in: what it

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[8] The Atlantic, 'How Google Builds Its Maps—and What It Means for the Future of Everything' at http://www.theatlantic.com/technology/archive/2012/09/how-google-builds-its-maps-and-what-it-means-for-the-future-of-everything/261913/

means is that dedicated people are tasked with deciphering images and transcribing them and therefore making them reusable in another context.

Necessary "Protocol Work" Between Data Sources

The presence of such activities to "make infrastructures work" touches a central theme of the sociological investigation of information systems. Combining work in sociology of science on the largely essential, yet unacknowledged role of technicians in scientific production (Shapin, 1989), the field of *infrastructure studies* has investigated information systems through the human activity upon which they depend (Star & Ruhleder, 1996): it led to the study of dedicated workers in charge of operations of maintenance, classification, or processing, for objects as diverse as urban transportation networks (Denis & Pontille, 2014) and ecological (Millerand, 2011) or biomedical databases (Dagiral & Peerbaye, 2012). These various sites of investigation highlight the precarity, invisibility, and unrewarding nature of such positions (Bowker & Star, 1999; Ensmenger, 2014). To summarize, this field of study asks *what activity is needed to make infrastructures work, who provides it, and under which status*.

Adopting such a perspective allows us to see the crucial role of human activity in updating the Google Maps database. It consists of "protocol labor" (Downey, 2014), comprised of activities by dedicated workers such as coding, delivering, or processing, to allow information and data to "jump contexts," by being put into circulation. Considering failure and breakdown as intrinsically present in infrastructures (Jackson, 2014), and not just an epiphenomenon, renders this human activity essential:

> No matter what automated protocols are in place at any given moment, they will be imperfect and incomplete; disparate information networks can only work together through the efforts of specific workers who maintain the links, transform the content, and police the boundaries between those networks. (Downey, 2001, p. 225)

What is the protocol labor present in Google Maps? The use of the term “elbow grease” by Google engineers is already an acknowledgement of the necessity of such adjustment through human labor, and it takes different forms depending on the type of digital traces to process. For participatory data such as suggestions of edits, a specific category of workers, called “Ground Truth operators,” is responsible for curating and verifying the accuracy of the edits suggested by users, by double-checking if the suggested edits correspond to real-world changes. Concerning the modularity of data between Google Street View and Google Maps, this task can come from dedicated operators hired by Google. In this case, dedicated staff has to review, curate images, and detect relevant information, following this simple question: ‘“Am I looking at an address or not?’ Click. Yes. Click. Yes. Click. No.”[9] But such task can also be completed by relying on crowdsourcing, through the ReCAPTCHA application. Since the acquisition of this technology by Google in 2009, it has been using this service to “crowdsource” the transcription of images from its various scanning projects, such as Google Books and Google Street View. A user will, for example, transcribe a house number through a ReCAPTCHA, that is, manually processing data from Street View, which can eventually be used to update Google Maps service. A third way is the reliance on algorithms:

> For other maintenance projects—say, updating speed limits throughout a state or town—we can use information that is going to be automatically detected through Street View technology and algorithms.[10]

Updating maps is therefore obtained through a configuration that rely on a combination of hired operators, crowdsourcing, or algorithms.

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[9] *Wired*, ‘Inside the artificial brain that’s remaking the Google empire’,: http://www.wired.com/2014/07/google_brain/

[10] *Huffington post*, ‘Life As A Google Maps Editor: Screening Thousands Of Corrections And Making Maps By Hand.’

What we saw in this part is that as platforms grow to the level of infrastructures, the status of participation changes: Google Maps engineers have less and less need for participation as content creation, but more and more for correction and verification of existing data, that is, the maintenance and correction of an existing database. This evolution has consequences for the nature and the status of participation: first, participation goes beyond the simple inputting of data to also provide a “protocol work” to organize the modularity between different data sources, here from Google Street View to Google Maps. Second, participation is increasingly mediated by algorithms, as it is channeled to make sure that algorithms “work” properly. Finally, participation is only used as long as it is the most efficient way of accomplishing a task, and constitutes one way among others (along with hired operators or algorithms) to conduct it.

The Recentralization of Knowledge by Mapping Platforms

We saw that the field of infrastructure studies provides a detailed account of the labor Google Maps relies on to update its geographic database. Specifically, it highlights the diversification of tasks assigned to public participation, thus not only providing content but also performing maintenance tasks. What are the larger consequences of this transformation of public participation in creating, using, and maintaining spatial knowledge? Critical perspectives on digital platforms ask such questions through the prism of the dynamics between openness and enclosure of knowledge in society. Relying on this perspective shows how Google Maps benefits from the decentralization of cartographic knowledge production, through multiple forms of participation to feed its maps; however, it also shows that this openness simultaneously comes with new forms of recentralization. Google Maps operates in the very competitive environment of mapping platforms, and the goal is to provide the best map possible, that is, the one that others will use for their mapping needs, similar to what an infrastructure would do. Participation is therefore channeled towards the goal of possessing the most accurate and updated maps, to gain a comparative advantage towards mapping services.

Decentralization with Recentralization

Langlois and Elmer (2013) highlight how economic logic shapes affordances of platforms and therefore participation. What they call "double articulation" highlights how the communicative mediation that constitutes social media platforms is "folded" within an economic logic. Van Dijck and Poell (2013) similarly analyze how platforms create and extract values from participation, through processes of datafication (in which every interaction on a platform can be transformed into data) and commodification (in which these data can be monetized). This body of critical research therefore goes beyond a vision of platforms as simply connecting people to analyze instead the circulation of data, value, and labor. It complements the focus from infrastructure studies scholars on human activity and its status, by highlighting the dynamics combining decentralization of participation and recentralization of data and information (Helmond, 2015): How is the decentralization and recentralization of knowledge operated through platforms, and who benefits from it?

As we saw in the previous section, Google Maps clearly operates by decentralization of its data collection modes. Adopting the properties of platforms, it has a great interest in having its mapping product being freely accessible (i.e., free to use), as well as having its base map customizable for third-party applications: both are ways of occupying the sector of geospatial data provision and collecting the widest amount of data from direct participation or usage traces.

This decentralization simultaneously comes with recentralization of data flows to feed the interests of Google Maps. After entering the geospatial sector in 2005, Google needed complete control over the provision of cartographic data used for its geographic database. This was the main rationale behind creating the project "Ground Truth" in 2008: It aimed, according to Brian McClendon, then vice president of engineering for Google Maps, "to build [their] own maps from scratch" (Kelion, 2012, para. 12). The

Google Truth engineers presented the goal of this project as changing Google Maps from a "video rental"—that is, renting base maps from other data providers and simply displaying them—to becoming a "movie production studio"—producing their own mapping data (Weiss-Malik & Lookingbill, 2013). This strategy aims to lower the dependency of Google on other sources of data (such as geospatial images from private companies, mentioned above) by developing its own data provision strategy. As McClendon describes: "We would start with licensed data and we would find whatever we could where we could get full rights to the data and improve it from there" (Kelion, 2012, para. 12). The diversification of roles for participatory data fits exactly within this goal.

In this context, participation in mapmaking is channeled and used in conjunction with other inputs to provide a map whose quality is recognized as the "best one" and is available for others to develop third-party applications—a service that an infrastructure would provide; however, such programmability ultimately serves the goal of Google: more users means more data, which eventually reinforces the position of Google Maps as the obligatory passage point in terms of mapping provision.

More Participation, More Enclosure

This dual logic of decentralization of public participation and recentralization around a single entity has consequences for cartographic knowledge production in society. As we saw earlier, the platformization of cartography that occurred in the mid-2000's resulted in an "opening" of the map, where several actors contested the traditional monopolies of agencies and satellite companies through multiple mapping initiatives (Plantin, 2014). In this context, participation was both a factor and a result of this opening of mapmaking: multiple forms of participation in maps were designed, which in turn triggered new innovative communication practices based on maps. Cartographic information was decentralized, and participation was key in this process.

More than 10 years later, what we are seeing is that a handful of these projects have evolved to adopt infrastructural properties, such as Google Maps. However, this has not resulted in the public provision originally associated with infrastructure. Instead, mapping capacities are channeled towards a corporate agenda: being recognized as the best map so others will use it. Google is leveraging on the openness of the map, while channeling the multiple forms of participation it allows to reach a competitive advantage against rivals, and eventually recentralizing it around its own private interests. Whereas traditional mapping institutes were meant to serve cartographic public needs, Google Maps provides the same service, but ultimately to serve Google's needs.

We therefore arrive at the paradox that defines current digital cartography. On one side, maps have never been so accurate and accessible: They possess a wide territorial coverage and are updated in almost real time; they are interactive and customizable, adapting to users' needs; people can contribute to them and they are free to use. But on the other side, maps increasingly serve private rather than public interests, similar to the monopoly of political elites and private patrons that has characterized mapmaking for centuries, before public institutes stepped in and administered mapping efforts with society in mind. The more participatory maps have become, the more enclosed they have become as well.

Conclusion

This article advances two main arguments. It first shows the evolving status of participation in Google Maps, changing from content creation to activities of maintenance as the project moves from platform to infrastructure. As maps behave like knowledge infrastructures, the maintenance of existing database is what is needed, beyond content input. The evolution of the roles assigned to participation in Google Maps illustrates this change. Second, this article shows the fragmentation of cartographic knowledge that results from the rise of Google Maps as an infrastructure. In this configuration, Google Maps aggregates digital traces to obtain a constantly updated map, but does not abide by mandates of accessibility and dissemination of knowledge that traditionally correspond to the social role of knowledge infrastructure. Whereas the platformization of the map in the mid-2000's consisted of a *decentralization* of mapping capacities through both the contestation of existing actors (mapping institutes) and the rise of new actors (OpenStreetMap, Google Maps), the infrastructuralization of maps through Google Maps operates a *recentralization* around private interests. The goal for Google is to reach a virtuous circle, where being recognized as the most accurate map increases the number of users, who then generate more digital traces, which are aggregated to constantly update geographic database, therefore making Google Maps effectively the most accurate map.

I arrived to these results by operationalizing a selection of authors from both fields of infrastructure studies and platform studies who have developed critical accounts of how each configuration organizes access to and participation in knowledge in society. Critical infrastructure studies scholars call for the investigation of the labor and maintenance needed to make each configuration work, and platform studies scholars investigate how the circulation of knowledge can be reorganized to serve specific corporate actors. The rationale behind mixing infrastructure studies and platform studies, traditionally separated by disciplinary lines, is to reflect the hybrid entities that populate the Web, such as Facebook or Google, that use networked and data-driven communication capacities, and which mix properties of platforms with those of infrastructures (Plantin et al., 2016).

Based on the case study of this article, what inferences can we make concerning the evolution of the role of participation in mapmaking? We saw that the form it takes is highly dependent on contingent needs of a specific mapping project. We also saw that participation is competing with other forms to complete the same tasks (hired operators or algorithms). The status of participation therefore seems precarious at best, and may disappear altogether if another way of updating maps is found to be more efficient.

Looking at the current evolution of the geospatial Web, there are also reasons to think that cartographic knowledge will be more and more fragmented through the multiplication of private platforms adopting an infrastructural scale. Motivated by mobile applications and autonomous cars business opportunities, multiple companies would like to lower their dependency on Google Maps and are currently investing heavily on developing their own mapping capacities. Following the model of Google Maps, this independence of mapping capacities is achieved either through using drivers as sensors to obtain geographic data,[14] creating a personal fleet of cars to take pictures and other measurements [15] or even acquiring existing geographic databases [16] Such large investments in mapping capacities could result in the multiplication of mapping projects that, like Google Maps, reach spectacular exhaustivity and quality, but which use this data to serve their own purposes exclusively.

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