

Mobile Mapping

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Sam Hind, University of Siegen, Siegen, Germany (hind@locatingmedia.uni-siegen.de)

Glossary

Black-boxed: Systems with opaque or unknown functionality in which only inputs and outputs are known or made visible. Derived from software engineering and used in actor–network theory (ANT).

Dataflows: Trackable and traceable packets of data usually personalized and attributable that have proliferated with digital, mobile mapping capabilities.

Datapoint: An individual entity or unit of observation. Routinely created by interaction with digital phenomena.

Ego map: Mapping functionality that places the user at the center of a map, ordinarily afforded by GNSS capabilities.

Geodesy: The scientific measurement and calculation of the Earth's properties. Fundamental to the development of geographic coordinate systems and GNSS.

Geodata: Aggregated entities or units of observation with a spatial or geographical quality.

Global Navigation Satellite System (GNSS): General term for any constellation of satellites enabling autonomous digital geolocation and navigation.

Global Positioning System (GPS): The US Military–developed GNSS in civilian operation since 2000, used around the world for geolocation and satellite navigation.

LiDAR: A surveying method involving the calculation of distance according to the speed at which light is reflected off objects. Used widely in geodesy, geomatics, agriculture, and forestry. Also currently being tested in autonomous vehicles.

Mapping assemblage: An array of cartographic objects, processes, protocols, features, and infrastructures required to enable a map to function.

Mapping moment: A methodological framework for understanding how maps are used in specific events or for specific occasions.

Portolano: Early descriptive documents used by mariners from the 13th Century to ensure safe navigation through open waters. Often used together with portolan charts.

Slippy map: Mapping functionality that allows for seamless digital map visualization and interaction.

Turn-by-turn navigation: Mapping functionality enabling dynamic, automated road navigation as map users approach decision-making points. Made popular by in-car GPS.

Introduction

Mapping has always concerned mobility. The extent to which various aspects and stages of mapping are mobile, however, is a more complicated issue. Long before hydrographic surveys and alongside portolan charts, 13th-Century mariners were using portolanos to aid navigation throughout the Mediterranean Sea. These written documents, as historians have noted, ensured seafarers avoided dangerous obstructions, followed recognizable coastal landforms, and successfully negotiated harbor approaches. In essence, they served the same general, navigational purpose as any location-enabled map “app” does in the 21st Century. This is despite the passing of over 720 years since the first, still surviving, portolano was written.

In the last 10 years there have been unprecedented developments in the form, scope, spread, cost, and integration of mobile maps, mapping, and navigation into, and across, contemporary society. These developments constitute a consolidation of mobile mapping into everyday life, for many, around the world. Google Maps launched their mobile map application on Android and iOS systems in September 2008. Version 9.85.2 was released in August 2018. Uber, a ridesharing platform built around a mobile map, reached a valued of US\$72 billion in the same year. A new generation of mass market, dual-frequency GNSS (Global Navigation Satellite System) chips will afford positional accuracy to 30 cm. According to the European Global Navigation Satellite Systems Agency (GSA), almost 8 billion devices will have geolocative capacities by 2020. While the immediate market for GNSS is predicted to decelerate from 2020, revenue from “added-value services” such as autonomous vehicles will hit US\$228 billion in 2025. Digital, commercially available mapping platforms can now be considered rudimentary and ubiquitous.

Despite the prevalence and widespread use of digital, mobile mapping platforms, there have been many incremental and at times, intensely disruptive changes to the production, circulation, and deployment of mobile maps. Many of these developments have entailed huge transformations in the way mapping data are collected (geodetic surveys, crowdsourcing), stored (commercial databases, the cloud), visualized/optimized (small screens, touchscreens), and used (platform integration, interoperability). The developments will continue to affect the way mobile maps are used, and mobile mapping is practiced, well into the 21st Century.

Principles and Shifts: Surveys to Automation

Geodetic surveys provide the foundation to mobile maps, and mapping, as they are known now. The theoretical principles of geodesy were established by Greek, Roman, and Arabian mathematicians, philosophers, and geographers between 580 BC and the 12th Century CE. Pythagoras, Ptolemy, and Muhammed al-Idrisi are variously credited with advancing understanding of the Earth and its various properties; before being taken up by Enlightenment thinkers in the 16th Century. Modern geodetic surveys were commissioned by nascent nation-states, such as France and the United Kingdom, in the 18th and 19th Centuries. Such theoretical and practical efforts have become necessary building blocks for the development of global geodetic data and geographic coordinate systems, upon which satellite navigation systems now rely. Without these standards and protocols the modern mobile mapping industry would look very different.

“Ego mapping” has radically changed the relationship between the map reader and the map. Up until the development of GNSS, map readers would be forced to reorient themselves in relation to the map. Even before the civilian rollout of GPS (Global Positioning System) in 2000 and the subsequent ability to place oneself “in” the digital map, usually courtesy of a colored dot, the map reader no longer had to calculate their location, nor their direction of travel. Instead, this was calculated automatically by a GPS-enabled device in the hands of a navigator; whether a pilot traversing the Atlantic Ocean, a hillwalker climbing a mountain, or a delivery operator driving down a city street (Fig. 1).



Figure 1: Ego mapping and orientation. Courtesy: Jana Wendler.

The embedded shift in this development was that navigation using a map on a mobile device became even more “task-focused,” with readers able to glance at a dot dancing across the map, and be constantly reassured of their position. Map users, in this sense, have become ever more “cartographically anxious”; eager to follow every movement and change of direction. As a result of the shift to ego-centric maps, the act of navigation has become increasingly integrated into daily practices; with map readers able to locate and orientate themselves in seconds. Beyond this, map readers are now able to **use** widespread data connectivity to make use of mapping on demand, and in response to immediate navigational needs.

Within this more general shift to ego-centric mapping, many concomitant developments can be witnessed that have transformed the embodied nature of mapping “on the move.” Neither smartphones nor tablets utilize established desktop peripherals for issuing commands such as keyboards and mice. Instead, they offer touchscreen capabilities in which device users are able to issue commands via a flat, transparent surface or “double interface” affording both input and output. In this development, map readers are able to feel their way across the map; pawing, stroking, and tapping the screen. These interactions with the map are qualitatively different from the mechanical jabs of individual keyboard letters, or the instrumental clicks of a computer mouse. As such, they have transformed what it means to “read” a map (Fig. 2).

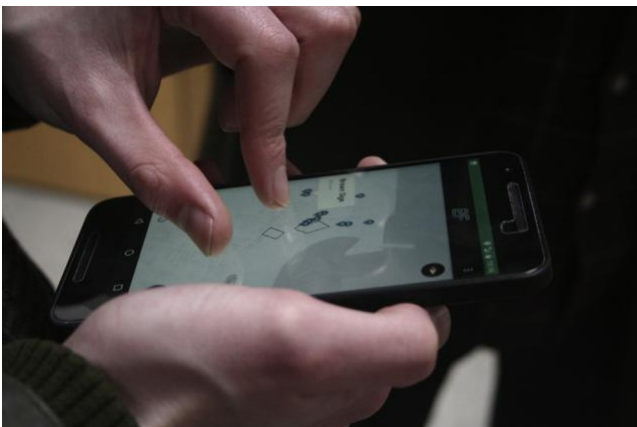


Figure 2: Touching the mobile map. Courtesy: Jana Wendler.

Mobile devices are designed to be operated in motion. As a result, there are limitations on their ideal size, shape, and weight. Although manufacturers have continued to push the upper limits of acceptable device dimensions, screen sizes and therefore map display sizes remain restrictive. Although the shift away from paper maps has brought benefits, one considerable effect has been the need to offer creative cartographic styles in order to render data appropriately. This is what cartographers have referred to as the paradox of mobile maps; offering comparatively “meager” outputs in response to “sharp” user requirements. While all maps require a careful selection of relevant data, this selection process has taken on a new and novel shape

in the mobile world. “Dynamic zoom levels” are one such way in which cartographers have sought to toggle important cartographic content and labeling; optimized for a mobile device. These, in effect, allow the cartographer to nest many maps in one “Russian Doll” mapping interface. Road names, retail locations, 3D building models, and other such features present themselves at varying levels; dependent on their perceived relevance to the map reader. As a result, this allows the user to zoom into the map, encountering features that variously present themselves at different scales. This provides for a qualitatively different and mobile map-specific experience.

Automation has had a significant effect on mobile map use. Digital map users are now no longer required to calculate where they are located, or may be headed. While GPS is able to pinpoint civilian users to within a few meters, route calculation algorithms packaged within mobile mapping software are able to generate A-to-B journeys using road network data. Turn-by-turn navigation is now found in GPS (TomTom, in-car systems), mobile map apps (Google Maps, MAPS.ME), social map apps (Waze, Strava), and handheld devices (Garmin, Navman). Such advances have redefined the cognitive and embodied act of navigation. Automation has also affected mobile map use in other ways. Query suggestions embedded within map search bars, otherwise referred to as autocomplete have sped navigational inquiries up, while minimizing search errors. Other features such as autocorrect have limited the misspelling of place, road, and house names. The result is a streamlined navigational experience.

A related contemporary feature of mobile maps is live traffic integration, predicated on adding a temporal overlay to base maps. Such features render the digital, mobile map responsive and reactive to changing conditions; something other cartographic forms struggle with. The “liveness” of such maps is open to interpretation, however, with most offering only “near-real-time” as opposed to actual or “real-time” mapping of phenomena such as commuter traffic. Nonetheless, such overlays present the possibility of a radically dynamic map; one pulsing with the flow of vehicles. For the map reader, it presents a radically dynamic navigational experience, one updateable and changeable dependent on a variety of factors such as traffic volume, traffic accidents, roadworks and other such facts of driving life across many if not all parts of the world. Other overlays in the form of Augmented Reality (AR) or Head-up Displays (HUD) offer fascinating glimpses of a mobile mapping future, in which cartographic data are presented in user’s Field of View (FOV); an option with relatively limited application thus far.

The most intensive societal disruptions are likely to take place in the automobile industry, as live data collection techniques and the automation of driving combine to offer semi- or even fully autonomous vehicles in the next 15–20 years. This development promises to take mobile mapping into new territory, as a greater suite of navigational responsibilities are surrendered to the vehicle and its constituent sensor technologies and systems (LiDAR, cameras, wheel sensors, GPS). Although humans are unlikely to lose the “art” of map reading, new technological innovations will continue to shift and rearrange the roles, responsibilities, and risks intrinsic to mobile map use. These innovations will undoubtedly transform the way we navigate, perceive, and move through complex environments.

Theories and Conceptual Developments: Mutability to Interface Effects

Mobile mapping has been theorized in many ways, both in and beyond human geography. Actor–network theory (ANT) and process philosophy, for example, have focused attention on the mutability, fluidity, and transformative nature of mobile maps. Anthropology and mobilities research has sought to define, and articulate, the conditions of mobility itself. Human–computer interaction (HCI) and media studies have explored the relationship between mobile technologies and their effects on human experience, skill, and decision-making. Many of these approaches acknowledge and even integrate earlier structural critiques of mapping. In general, these varied approaches offer performative, hybridized epistemological accounts through which the map itself is decentered, sociotechnical networks are analyzed, and gestures and actions

are scrutinized. Together, these approaches have enabled a sharper interrogation of the ontological shifts witnessed in mobile mapping over recent years.

Actor–network theorists have often applied the term “immutable mobile” to mobile mapping. An immutable mobile is an object that possesses a fixed form, physically and conceptually, that enables it to “travel” beyond its immediate environment. As a famous ANT tale goes, in the late 18th Century a French explorer called La Pérouse was instructed by Louis XVI to bring back maps of Northeast Asia. Part of the task was to determine whether Sakhalin was an island. For the local population, paper maps were largely unnecessary. Endless outlines could be drawn, and redrawn, in the sand along the Sakhalin coast. These maps were “mutable” with no explicit need to be “mobile.” La Pérouse, however, needed his maps to be transportable. Navigational, calculative, and scientific devices on board his ship ensured a “translation” from sand to paper could proceed, with the otherwise mutable, hand-drawn sketches of Sakhalin becoming “immutable.” A vast array of rules, systems, and objects such as map projections, marine clocks, and log books ensured that accurate maps of the island could be rendered. Further, of course, that these maps could become thoroughly mobile, returned to imperial France as evidence of the scientific exploration of foreign, unknown lands.

Contemporary digital, mobile maps, as other ANT scholars have argued, are better conceived as “mutable images.” Many features of the digital, mobile map are no longer immutable. Indeed, they have a “refreshability” to them, with visualizations generated on a task-by-task basis according to requests and demands, as suggested in the previous section. Digital navigation necessitates such a mutability, reliant as it is upon an ever-changing cartographic form squeezed into the spatial limits of a mobile screen. Considering mobile maps as mutable images has complicated the idea of the map as simply, and only, an immutable mobile. As will be explored later in this section, the immutability of the mapping enterprise has not been eradicated entirely.

Process philosophers have also illuminated the importance of “flows” and “lines” in mobile mapping. In particular, the term “lines of flight” has been used to study particular trajectories: the repetitive rhythms of humans; the migratory movements of animals; or the conceptual journeys of words, ideas and affects. These flows, in process philosophy, constitute contingent, open, nonlinear lived experiences. As such they have a specific connection to mobile mapping practices, as cartographers have found in grassroots mapping initiatives. Cartographic inscriptions craft out spaces of possible, necessary, or legal movement across actual space limiting where map users are able to go. But cartographic inscriptions can also track movement itself, rendering instead a route taken. The ubiquity of GPS functionality in many mobile devices (smartphones, fitness trackers, watches) and mobile objects (bikes, cars, trucks, ships) is integral to this possibility, as discussed in the previous section. Flow-thinking, therefore, is able to articulate these technological advances; being suited to a changing world in which many people and things are geolocated, tracked, and mappable.

Anthropologists, besides others, have also written extensively about lines. Some types are well known to cartographers, such as the unerring, authoritative lines that demarcate territory. But there are also other kinds that constitute movement and mobility in different ways. There may be network lines comprising of “chains of connections” drawn between distinct points, such as on metro maps. These lines are straight and unyielding; constituting necessary routes along which, for example, underground passengers must travel aboard a train. Each point constitutes a momentary break in this movement; a station or port of call. But there are also wayfaring lines. These are the movement lines of, to use another famous example, the Orochon people of north-central Sakhalin. Returning to the same island as before, this anthropological focus is on reindeer-drawn sleds, rather than sand-drawn maps. Unlike “destination-oriented” transportation, wayfaring entails the movement across land or sea without these distinct, isolated connecting dots. Instead, hunters and seafarers remain attentive to the “smooth,” fluid (figurative or literal) environment they inhabit. The inscriptions these movements provide, if one were to mark and trace them, comprise what has sometimes been called a “meshwork” (as opposed to a network) but could quite easily also be referred to as mobile maps (Fig. 3).

Figure 3: Meshwork and network. From Ingold (2007).

Mobility scholars have extensively critiqued im/mutability, flow and movement lines, reminding human geographers of the “relationality” of mobility and the importance of understanding the infrastructures of mobile mapping. While the digital, mobile map is arguably mutable, it has become reliant upon a welter of immutable mobiles; everything from data protocols to mobile cell towers. Transformations in mapping continually threaten to redesign these immobile infrastructures, reconstituting mobile “mapping assemblages.” For digital, mobile maps to work, many more features and functions are distributed geographically distant from the immediate map user. This has enabled more object-oriented, materialist, and computational approaches to mobile mapping, with attention switched to infrastructural and “protocological” features. Some of these changes will be discussed in the following section, as they provide ongoing methodological and ethical issues for researchers of mobile mapping.

Work on the boundaries between human geography, HCI, and media studies has also accelerated theorizations of interfaces and screens. Although typically both are seen only as technological components, some have challenged this common sense assumption. Media theorists, for instance, have considered interfaces as producing “effects,” generating responses from both human and nonhuman users, not limited to the technical dimensions of the physical interface itself. Those in HCI have likewise analyzed the “user interface” and the “user experience” by deconstructing mapping interfaces into component parts that “invite” or “afford” human interactions. Other media theorists have conceived of interfaces in even more general terms; returning to the word’s original 19th-Century use. In foundational work in engineering on fluid dynamics, an interface was a contact point between “two expansive territories” (water, mud etc.). As a result, the interface escapes its narrower definition as a component of, say, a smartphone or GPS device. In other work by media scholars, the “screen” is cast as thoroughly mobile; working to limit and shape interaction through and with the wider world. Novel “visual regimes” are cast accordingly. Similarly, human geographers have paid attention to the embodied form of these relations between technology and user, positing that a wide array of mobile interfaces transforms our movement through space.

What binds these varied theoretical accounts together is an appreciation of the connected, coproductive, and co-constitutive form of movement relations between technological components, digital devices (mostly), and users, as well as the inevitable gestures, decisions, and actions generated through these shifting relations.

Methodological Questions and Ethics: Geodata, Failure, and Permissions

A multitude of methodological questions and ethical issues have emerged in recent years that complicate the rise of mobile mapping. Most of these have centered on its digital and social dimensions, highlighting the ease at which personal geodata can be collected and associated issues with doing so. Other questions include the methodological value of mapping failures, ethical issues surrounding “dataflows” and permissions, as well as emergent pushbacks against these problems. The features of, especially digital, mobile mapping provide complications both for users and researchers of such technology.

New methods have enabled researchers to identify, track, and trace digital “datapoints” generated by web users in their daily transactional lives. These datapoints may comprise, for instance, online purchases, social network posts, or website visits. Many of these online interactions have a “geo” dimension, at different scales and with varying granularity. Amazon can ship packages to home addresses, offices, or through their own distributed locker system, while Twitter users can select the country they live in from their user account menu, add the city they live in to their public profile, choose to turn a precise geolocation functionality on with every tweet they send, or attach a hashtag that can invariably be used as a location proxy. “Big data” approaches have made it easy to capture, categorize, and analyze the geographical dimension of this digital, social life.

As some human geographers have suggested, more work needs to be done to understand the significance of geolocate markers such as self-inputted country codes, city names, latitude/longitude coordinates, and hashtags. Similarly, other geographers have suggested the need to find a way to express cartographic practice beyond the use of GPS coordinates as socio-spatial proxies. Aggregated datasets may say something about the composition of online publics who uses social media and who doesn't but do not replace work done to explore how, and contextualize why, people use digital, mobile media.

As a way to focus research on mobile mapping, other scholars have used new framing devices to delineate changes in how people (and things) make and consume maps. Some have composed manifestos in which mapping "modes," "methods," and "moments" could be taken as appropriate framings to rethink maps. Some of these modes, such as interfaces and infrastructures, have been discussed in previous sections. These are, in essence, the ontological aspects of mapping. Different methods and methodological approaches focus attention on aspects of the mapping enterprise, from its materiality to its affective and ethnographic dimensions. These, in short, are the epistemological dimensions of mapping. Focusing on mapping moments, however, draws increased attention to the spatio-temporal dynamics of such a practice, arguing that where and when we map radically alters how we conceive of them.

Moments of "mapping failure" constitute events that radically affect how we consider maps and their mobility. Ostensibly they occur in different degrees, from the catastrophic to the routine. When Apple Maps launched in 2012, users were faced with a multitude of issues. Satellite imagery appeared to have "melted" in a surrealist fashion, places were mislabeled, and other kinds of map data were duplicated, out of date, or erased completely. Apple blamed these errors and glitches on its data providers, rather than the map itself. In truth, they amounted to processing issues, a failure to integrate various sources of data into Apple Maps. In this catastrophic event, the otherwise "black-boxed" Apple Maps platform was opened up to scrutiny. Without such a failure, these internal mechanisms would have remained invisible. Mobile mapping is reliant upon the sometimes precarious alignment of digital platforms and infrastructures that do not always, quite literally, "map" onto each other. Scrutinizing these moments of failure allow us to see mobile mapping as a contingent, labor-intensive endeavor rather than a taken-for-granted operation.

Other such failures are more banal. Digital, mobile maps depend on a functioning mobile communications network. According to GSMA, 2G LTE usage accounts for 40% of mobile access worldwide, with 3G accounting for 31%, and 4G for 29%. 5G is projected to account for 14% by 2025. Yet mobile communications are not available everywhere and require the presence of mobile cell towers to operate. In many rural areas with challenging terrain, throughout the world, this physical infrastructure is either inadequate or missing entirely. As such, digital, mobile map use is rendered difficult if not impossible. These cartographic failures may be experienced in several ways. Search queries can take longer to be executed, loading for seconds or minutes. Raster map tiles integral to the generation of "slippy maps" may take a similar time to individually appear. Live traffic data may be rendered unavailable. These kinds of mapping failures, although apparently small or inconsequential, affect the day-to-day utility of the digital, mobile map for people around the world. While it is assumed such platforms are infallible, and while catastrophic failures are rare, failures of all kinds are a feature of digital life.

The Apple Maps debacle shone a light on an emergent cartographic landscape. Mobile map products are necessarily built on the provision and integration of various kinds of data, each in their own format, with their own provenance, validity, and granularity. These datasets are may be built or acquired, either composed from users in the form of free "volunteered" labor (Tripadvisor, Google, OpenStreetMap, Wikipedia), derived from centralized databases (city or state records), purchased from other propriety companies (TomTom, Waze, Dunnhumby), or collected and stored independently (Google Streetview, Uber). Different data acquisition, storage, and valuation models are splintering and fracturing this landscape in new ways. As a result, there are growing methodological questions and ethical issues that digital scholars are minded to address. These respective problems fall into two categories: approach issues and subject issues.

For researchers accessing such data, assurances need to be made that this is appropriately aggregated, anonymized, or otherwise protected from individual attribution. Datasets, as Geographical Information Systems (GIS) scholars are well aware, are easily “joined” to other datasets by common categories (phone numbers, MAC addresses, postcodes). While specific datasets on their own might not reveal sensitive information, once combined with other datasets there is an increased likelihood that such sensitive information is inferable or revealed. Geodata derived from mobile map used such as location check-ins must be carefully considered by researchers, not least because some location data (cell tower “pings,” etc.) are accumulated unbeknown to, or hidden from, mobile users.

Permission type	Detail
Identity	Find accounts on the device Add or remove accounts
Contacts/Calendar	Read your contacts
Location	Approximate location (network based) Precise location (GPS and network based)
Phone	Directly call phone numbers
Photos/Media/Files	Read the contents of your USB storage Modify or delete the contents of your USB storage
Camera/Microphone	Take pictures and videos
Wi-Fi connection information	View Wi-Fi connections
Device ID and call information	Read phone status and identity
Other	Use accounts on the device Read Google service configuration Modify system settings Full network access Control vibration

Table 1: Uber app permissions. Based on Uber’s Android app permissions.

For researchers specifically interested in the ethical, political, and sociotechnical aspects of the mobile mapping industry; GPS tracking, satellite navigation, and the personalization of dataflows are increasingly being seen by users as problematic and undesirable by users. Most mobile mapping platforms depend on the acceptance of geolocate permissions to operate, limiting the extent to which users can interact with such services without personal geodata being collected or stored indefinitely (Table 1). Google Maps requests geolocate permission each time its mobile app is launched, Waze will only run if GPS functionality is turned on, and location features are integral to the operation of dating apps such as Tinder and Grindr. The rise of differential geolocate options and access permissions on mobile apps, as GIS scholars have argued, has resulted in making many especially female users more vulnerable to “unsolicited advances” on such platforms; being greater exposed to “creepy” online behavior by other users. These technological, infrastructural, and protocological features have opened up new interpretations of surveillance in a mobile media age, rendered not by an all-seeing, “panoptic” nation state, but by “oligoptic” corporate entities. Scholars in human geography and cognate disciplines are becoming increasingly interested in the effects of these features on everyday life, societal norms, and expectations of privacy and security (Table 2).

At present, pushbacks against such ethical issues in mobile mapping have been limited. Broader efforts to prevent online tracking, such as with Mozilla’s Firefox browser and the DuckDuckGo search engine, have not integrated concerns of map use tracking. Mapzen’s map app, Eraser Map, sought to solve some of these issues when it was launched in beta mode in 2016. The app involved Mapzen developers having to create an Android Software Development Kit (SDK) to replace Google’s location functionality, otherwise integrated into usual

mobile mapping platforms. The company’s “full stack” approach, however, enabled it to use a bespoke mobile app, map display, search engine, turn-by-turn navigation, and copyright-free map data. This allowed beta testers to use the mobile map app without the fear of being tracked, or their data being compiled to generate user profiles for advertising purposes. Mapzen’s abrupt closure in 2018 highlighted the difficulties open-source mapping projects have faced in escaping the dendritic reach of major technology firms such as Google, Amazon, and Facebook. Mobile map scholars continue to critically evaluate the economic, cultural, and political factors that drive socially minded enterprises in a largely capitalist carto-graphic world.

Summary

Mobile mapping has a long history not limited to the digital era. Yet everyday life for many, directly and indirectly, is now shaped by digital devices, platforms, and infrastructures. This article has identified some of the principles of mobile mapping, charting the shifts in both the mobile and cartographic features of this practice. Where once geodetic surveys and triangulation methods stood at the forefront of mobile mapping efforts, now the use and ubiquity of mobile devices such as smartphones and location-aware objects occupy this space. Some geographers have suggested that the “electronic transition” would bring the greatest changes in cartography since the 15th Century (printing, sailing) and 17th- to 19th-Century revolutions (colonialism). If we are to contextualize this electronic transition or what many refer to as a “digital revolution,” then mobile mapping comprises a small, but significant part of this era. Incremental changes to the mobility of this practice of locating; tracking; and mapping people, animals and things look set to continue well into the 2020s. Mobile mapping, in other words, constitutes a consolidation, extension, and calibration of broader digital transformations.

Privacy feature	Detail	Products and services built, used or requested
No user accounts	Most mobile map services require individual user accounts.	N/A
Minimal app permissions	All mobile apps require users to permit feature or component access on a mobile device (see Table 1).	Wi-Fi/Mobile network information Location
Data stored on device	Most mobile map apps store data on individual devices, as well as uploading data to servers.	Map tiles cached Map searches cached Search history can be deleted LOST (custom-built location API)
No invasive third-party SDKs	Mobile apps routinely use third-party software to provide functionality, analytics, and crash-reporting capabilities.	
Use of only two third-parties	Mobile apps depend on other platforms and services for functionality.	Amazon Web Services (cloud service) Fast (content delivery)
All open software and data	Many mobile apps use, and integrate open-source software and data. Users and developers can inspect code, flag issues, and suggest changes. Allows for increased scrutiny and trust-building.	Eraser Map (map app) Tangram-ES (map renderer) Pelias (geocoder) Valhalla (routing library) OpenStreetMap (map dataset) OpenAddresses (address dataset) Who’s on First (place gazetteer)
Limited utility of court-ordered legal server data requests	All companies must comply with legal requests for data stored on servers. As no data is stored on users, such requests of limited value.	N/A

Table 2: Eraser Map privacy. Based on Mapzen’s Eraser Map privacy policy.

Different theoretical lenses have been used to make sense of these transformations. ANT, process philosophy, and anthropology continue to be of importance and relevance to mobile mapping due to the varied interest and emphasis on relations, movement, flows, lines, translations, inscriptions, skill, and decision-making. Those working in fields and disciplines closely bordering human geography such as mobility studies, HCI, and media

studies have critiqued, refined, and reconsidered these major theoretical efforts, focusing on the interfaces and infrastructures of mobile mapping in equal measure.

Yet questions of a methodological, and ethical, nature are perhaps at their most pertinent now than at any point since the 19th Century. Only now is serious intergovernmental, multinational digital legislation being rolled out to comprehensively protect citizens in a digital, social, mobile age. The European Union (EU) General Data Protection Regulation (GDPR), adopted in 2016 to replace the Data Protection Directive, enshrined a series of “data subject rights” in EU law, including the right to erasure, the restriction of data processing, and the right to not be (wholly) subjected to algorithmic decision-making. All of these rights will have an effect on mobile mapping and its bundled features and functionalities.

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