Defacing the Map: Cartographic Vandalism in the Digital Commons

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This article addresses the emergent phenomenon of carto-vandalism, *the intentional defacement of collaborative cartographic digital artefacts in the context of volunteered geographic information. Through a qualitative analysis of reported incidents in WikiMapia and OpenStreetMap, a typology of this kind of vandalism is outlined, including play, ideological, fantasy, artistic and industrial carto-vandalism, as well as carto-spam. Two families of counter-strategies deployed in amateur mapping communities are discussed. First, the contributors organize forms of policing, based on volunteered community involvement, patrolling the maps and reporting incidents. Second, the detection of carto-vandalism can be supported by automated tools, based either on explicit rules or on machine learning.*

Keywords: carto-vandalism, online vandalism, crowdsourced cartography, volunteered geographic information, OpenStreetMap, WikiMapia, commons-based peer production, digital commons

INTRODUCTION

Maps are widely recognized as powerful and versatile representations of geographic realities, loaded with cultural, aesthetic and practical meanings. Thanks to ubiquitous and inexpensive personal computers, smartphones and location technologies, mapping practices are currently experiencing a reconfiguration, driven by online modes of production, delivery and consumption, generating informational commons of reusable geographic information. These forms of crowdsourced cartography inherit well-established mapping conventions and traditions, but also present novel aspects that deserve attention (Dodge and Kitchin, 2013). Collaborative online mapping relies on commons-based peer production, almost entirely mediated by digital communication tools. As Benkler and Nissenbaum (2006) put it, commons-based peer production is a sociotechnical system that relies on 'collaboration among large groups of individuals … who cooperate effectively to provide information, knowledge, or cultural goods without relying on either market pricing or managerial hierarchies to coordinate their common enterprise' (p. 394).

In the geographic domain, commons-based peer production has transformed the traditional expert-driven models that had dominated the field. Goodchild (2007) used the term *volunteered geographic information* to describe the complex constellation of amateur mapping projects, while Graham (2010) identified in these phenomena a common drive to create virtual versions of places and geographic realities. In such projects, contributors form self-regulating communities to create, maintain and promote the usage of digital geospatial artefacts. Wikified maps, free gazetteers, mash-ups and open geo-knowledge bases create an inter-linked ecosystem of geospatial commons (Ballatore *et al.*, 2013). In addition, these large collaborations form a communal space in which individuals can engage with their geographic surroundings in novel ways (Elwood, 2008).

Among others, a major difference exists between traditional and commons-based peer cartography. Traditional cartographic production is conducted by experts in a private environment, which limits the possibility of malicious actions on the data. This is manifestly not the case in commons-based peer production projects such as WikiMapia and OpenStreetMap. This article investigates *carto-vandalism*, an emergent form of deviant behaviour in collaborative production environments directed at geographic information. Unlike online open datasets, physical geospatial artefacts can be vandalized only when exposed in public spaces, such as in the case of tourist maps and cartographic monuments. A notable instance of such vandalism can be found in the history of modern Italy, when in 1943 one of Mussolini's 'imperial maps' in Rome was defaced with red paint, symbolically attacking Fascism's geographic expansionism (Minor, 1999)[1].

Mutatis mutandis, the digital maps that are generated today through commons-based peer production suffer from a variety of forms of vandalism. Because crowdsourced cartography is intrinsically open to anonymous contributions, the core geospatial artefacts are highly vulnerable to malicious contributions. Commons-based peer production relies heavily on implicit trust in contributors, and on the goodwill of participants to construct value rather than

destroy it. For example, anybody can create an account and edit the vector map in OpenStreetMap, the most prominent peer production cartographic initiative, and see their changes immediately visible online. Whilst malicious edits on Wikipedia have been the object of much research, carto-vandalism, i.e. vandalism aimed at geographic artefacts, is a little-understood phenomenon. In the recent debate on the quality of crowdsourced geographic information, this kind of vandalism is often mentioned, but has not been analysed organically (Flanagin and Metzger, 2008; Mooney *et al.*, 2010; Goodchild and Li, 2012).

The perception of carto-vandalism plays a crucial role in the credibility – or lack thereof – of crowdsourced cartography (Flanagin and Metzger, 2008). Therefore, the stakes surrounding it are high. Unsurprisingly, crowd-sourced cartography advocates tend to minimize the severity and importance of carto-vandalism. OpenStreetMap's founder Steve Coast (2010b) argued that 'malicious edits are probably the least significant and will always exist' (para. 43). By contrast, commercial providers of geographic information cite vandalism as a serious flaw of crowdsourced cartography. In a promotional newsletter, the company TomTom (2012) claims that user-generated maps are 'wide open to attack' and therefore unfit for critical applications such as routing, generating particular anxiety by evoking the possibility that anybody can change the direction of one-way streets, with potentially dire consequences for drivers. Although both claims bear some degree of truth, they are influenced by vested interests, and a deeper understanding of the reasons behind carto-vandalism is necessary. The phenomenon of carto-vandalism can be observed from several complemen-tary perspectives. Volunteered geographic information is generated by online communities, through forms of network sociality (Wittel, 2001), and the weak social bonds that dominate such communities can indeed favour deviant behaviour[2]. Definitional problems surround the emotion-ally-loaded term 'vandalism', used to label a variety of behaviours whose boundaries are notoriously difficult to define and whose targets include buildings, vehicles, as well as digital artefacts such as websites (Goldstein, 1996; Williams, 2007). From a legal viewpoint, unlike other types of 'serious' cybercrime, such as the trade of child porno-graphy or credit card cloning, the vandalisation of digital commons constitutes an uncharted grey area.

This does not imply that carto-vandalism has no tangible consequences for projects and contributors. When vanda-lized, digital artefacts see their use value being diminished, and their appeal reduced. As a result, communities have to devote part of their scarce resources to policing and other anti-vandalism activities that are often dull and unrewarding for contributors. The possible causes and consequences of carto-vandalism need be discussed in the framework of the unique properties of crowdsourced cartography, emphasiz-ing the peculiarities that distinguish geospatial artefacts from other forms of digital commons.

The remainder of this article sheds light on these issues as follows. The next section discusses the continuities of digital carto-vandalism with physical vandalism, which has been studied from sociological and psychological stand-points. Based on a qualitative analysis of incidents reported in OpenStreetMap and WikiMapia, two prominent

volunteered geographic information projects, a classifica-tion of the multiple facets of carto-vandalism is proposed. Subsequently, currently adopted counter-strategies are surveyed. Finally, the last section draws conclusions, pointing out directions for future research about carto-vandalism.

VANDALISM, PHYSICAL AND DIGITAL

The term 'vandalism' refers to a variety of socially constructed phenomena, and no clear academic consensus has been established about its scope. Reviewing its many definitions, Moser (1992) suggested that vandalism is 'a hodgepodge concept that covers behavior for which motivations are extremely different' (p. 51). The definitions of vandalism differ as they take into account the caused damage, the motivation of the human actor and/or the context of the incident. Vandalism is a ubiquitous and visible social phenomenon, in which intentional damage was performed on a variety of objects, including buildings, public toilets, vehicles, furniture, infrastructures, as well as works of art such as paintings, monuments and sculptures. Most vandalism incidents are far from being random, senseless acts and several competing theories to explain its reasons have been proposed. A consensus exists around the general meaningfulness of vandalism as a form of social communication between the offender and an imagined or real audience. The next sections review theories of vandalism directed towards physical and digital objects, and discuss the issue of deviance in volunteered geographic information communities.

Physical vandalism

Studies on vandalism against physical objects have been conducted mostly in the broad framework of criminology, harnessing theoretical tools from social psychology and sociology, particularly in the 1970s and 1980s. The key preoccupation of these social science researchers is the reduction of such deviant behaviours, and their societal and economic negative consequences (Goldstein, 1996). South African criminologist Stanley Cohen (1973) outlined a broad and influential classification of types of vandalism, based on the offender's purpose. His classification includes the following categories: *acquisitive vandalism* (theft or looting); *tactical/ideological vandalism* (to attract attention around a political or social issue); *vindictive vandalism* (for revenge against somebody); *play vandalism* (unintentional damage resulting from children's games); and *malicious vandalism* (violent outpouring of rage).

In the same decade, Allen and Greenberger (1978) proposed an aesthetic theory of vandalism, focusing on its pleasure-arousing potential, which depends on the specific traits of the target objects. By defacing objects, offenders tend to alter their structure towards simpler configurations, and therefore, objects of complex design are more likely to be vandalized than simple ones. Fisher and Baron (1982) have argued that perceived social inequality is a key cause of vandalism, which is perpetrated as an iniquity resolution mechanism. Their model accounts in particular for vandal-ism directed at public property, conceptualized by offenders

as a symbol of an unfair status quo. Furthermore, Sutton (1987) expanded Cohen's classification, identifying a new type of vandalism, i.e. peer status motivated vandalism. Mostly conducted by groups rather than individuals, this type of vandalism is perpetrated to gain or maintain peer status, for example damaging a vehicle on a dare.

From a more conservative standpoint, Kelling and Wilson (1982) outlined their widely discussed 'broken window theory', claiming that minor crime such as vandalism alters the environment, and the resulting physical disorder tends to generate more serious crime. The linkage between low and high intensity deviance has been also stressed by Goldstein (1996) as a key motivation to counter vandalism. However, these theories do not seem to capture the aforementioned essential drives behind physical vandalism, and have been challenged as inadequate to explain the socio-structural conditions that cause crime (Gau and Pratt, 2010). Over the last two decades, attempts to counter physical vandalism have been predominantly conducted in the framework of 'crime prevention through environmental design', applying architectural design patterns to discourage deviant behaviour (Cozens, 2008).

Digital vandalism

With the emergence of online spaces in the 1990s, vandalism found new avenues of expression, as happened with other types of crime that soon appeared on the Web. The most common form of cybercrime is the defacement of websites, often for satirical or playful purposes (Furnell, 2002). Williams (2004) defined the term 'online vandalism' to refer to deviant behaviour in online communities, particularly the defacement of digital artefacts built collaboratively, often as part of cyber-bullying. The environmental structure of online spaces determines specific, peculiar aspects of online vandalism. The so-called 'online disinhibition effect' consists of a reduction in social inhibitions and constraints, fostered by the perceived anonymity, invisibility, asynchronicity, dissociative imagination and lack of authority in online spaces (Suler, 2004).

However, the many continuities between online digital vandalism and offline physical vandalism should not be understated, and it is important to avoid the trap of what Jurgenson (2012) named 'digital dualism', i.e. the tendency of overlooking the substantial intermesh between the online and offline. Similarly to physical vandalism, 'digital vandalism' generates a large number of low-impact incidents, is rarely reported, prosecuted and punished, and is – quite reasonably – perceived as a less serious threat than phishing, identity theft and other obviously harmful activities. The inherent openness of commons-based peer production projects makes them ideal targets for online vandalism.

Because of its global success and visibility, vandalism against Wikipedia is the subject of an active research area, thoroughly surveyed by Nielsen (2012). The open infrastructure of Wikipedia is subject to structural vandalism, i.e. damage that is regularly inflicted on the digital artefact at the core of the community efforts. The surprising success of Wikipedia relies on its ability keep such structural vandalism at bay, rapidly reverting suspicious edits. Users deliberately delete valid information or enter incorrect facts in Wikipedia with a variety of playful or malicious purposes.

Because Wikipedia, as a form of digital commons, does not host information of high economic value, such as credit card numbers, authorities tend not to devote resources to counter online vandalism. As a result, offenders have high rewards in terms of visibility and pleasure-arousing effects, and virtually no risk, a highly criminogenic combination. Predictably, articles about controversial topics (e.g. abortion, divisive politicians, sexuality, contested borders) tend to be vandalized more often than others, and correct, but damaging information is often removed directly by affected individuals and organisations. Notable cases of Wikipedia vandalism include obituaries of living celebrities, humorously incongruous facts, obscenities and political propaganda.

Deviance in cartographic communities

Crowdsourced cartography is sustained by complex social networks, in which individuals deploy an inter-dependent combination of physical objects (personal computers, servers, cloud computing facilities, GPS sensors and smartphones) and digital artefacts (datasets, websites, documentation and software tools). The purpose of such *ad hoc* communities is the development and the maintenance digital artefacts. Community members cooperate through a variety of social media, including mailing lists, forums, private e-mails, wikis, Web conferences and, to a limited extent, through face-to-face interaction such as mapping parties. These communities are formed around an explicit and shared purpose, coordinating and sustaining inter-personal bonds through a combination of online and offline communication. As in any human community, behavioural norms are established, and deviance from these norms is discouraged and sanctioned with a variety of incentives and punishments (Williams, 2006).

While the vast majority of literature analyses volunteered geographic information data – particularly OpenStreetMap (e.g. Haklay, 2010a; Mooney and Corcoran, 2012) – fewer studies directly observe the underlying communities. Amateur mapping communities are characterized by social, technological and geographic divides. Human geographers study volunteered geographic information as a social practice, focusing particularly on the inequalities between people and places involved in the generation of knowledge (Elwood *et al.*, 2012). Another dimension of study is that of the scope, motivations and conditions of commons-based peer production of maps.

In these contexts, social ties are less stable than in local communities, and the emotional attachment to the digital artefacts plays a crucial role in preserving the community from disaggregation. Digital cartographic artefacts, such as the OpenStreetMap world map, constitute the barycentre of the community, whose boundaries can shift considerably over short periods of time, with many new members joining and current members leaving. Coleman *et al.* (2009) have investigated the motivation of contributors, classifying them on a spectrum ranging from neophyte to expert authority. In their view, volunteered geographic information contributors act on some combination of eight positive motivations: (1) altruism; (2) professional or personal interest; (3) intellectual stimulation; (4) protection or enhancement of a personal investment; (5) social reward; (6) enhanced personal reputation; (7) self-expression; and (8) pride of place.

However, motivations of contributors are not exclusively positive. As Williams (2004) noted for virtual spaces, volunteered geographic information communities tend be made up of 'turbulent and shifting populations' (p. 15). Uncooperative and disruptive behaviour drains resources from volunteers, and generates tensions within projects (Wall and Williams, 2007). Amateur mapping communities are no exception, and suffer from trolling and cyber-bullying. For example, OpenStreetMap has been often disrupted by the deviant behaviour of a minority of individuals. Project founder Steve Coast (2010a) has directly intervened against deviance that plagues the community, advocating the 'disinfection' of the project from 'poisonous people' who 'drain, paralyse, slow, cause needless infighting and destroy the attention and focus of a community … are wrecking the time, focus and goodwill of the majority of contributors, creating dissent out of nothing and even purposefully breaking our data' (para. 8).

In the context of crowdsourced cartography, Coleman et al. (2009) have identified three negative motivations for contribution: mischief (general destructive behaviour); agenda (conscious purpose); and malice and criminal intent (personal gain). According to them, such motivations lead to a number of deviant behaviours, including: mass or partial deletes; non-sense (incomprehensible information); spam; offensive content; and misinformation. Although this classification is a useful starting point, it fails to discriminate between the diverse and deep motivations of deviant expressions of carto-vandalism. To date, no systematic analysis of vandalism occurring in the context of digital cartography has been conducted. The next section fills this gap by investigating different types of carto-vandalism.

A TYPOLOGY OF CARTO-VANDALISM

Carto-vandalism is an emergent phenomenon, and its boundaries are difficult to delineate precisely. Unlike general digital vandalism, carto-vandalism has a strong geographic component and bears an intimate relationship with places. The target of carto-vandalism is primarily a digital artefact containing geographic information, such as a vector dataset, a spatial database or a gazetteer. The classic economic notion of the *utility* of geographic information can function as the guiding principle to include or exclude a given action within carto-vandalism.

As utility is context-sensitive and subjective, some acts can increase the utility of an artefact for one group of actors, while reducing it for another, and in such cases, conflicts arise between groups with divergent views. Hence, an act of carto-vandalism *intentionally reduces the utility of a geospatial artefact for the majority of the users.* The definitional difficulties encountered when dealing with vandalism are particularly visible in crowdsourced cartography. Although the actor's intentionality is crucial to define carto-vandalism, it is often difficult to assess it in practice, resulting in a wide grey area of acts that might be due to incompetence rather than maliciousness, or a combination of the two. For this reason, it is very common for contributors flagged as vandals to claim that what they did was not vandalism, and controversies ensue.

In order to uncover the motivations of this phenomenon, a new qualitative analysis of real amateur mapping incidents was conducted. This analysis focused on the carto-vandalism incidents reported and discussed on the forums and mailing lists of WikiMapia and OpenStreetMap, two highly representative collaborative cartographic projects. These incidents provided the empirical ground for the typology of carto-vandalism outlined in this section and summarized in Table 1. The types of carto-vandalism identified in this classification, framed in the tradition of Cohen (1973), are not mutually exclusive, but can coexist in the same incidents. For example, incidents of political carto-vandalism often have a playful component. This typology also emphasizes the aspects that distinguish carto-vandalism from other types of vandalism.

WikiMapia is a commercial collaborative mapping project founded in 2006, 'aimed at marking all geographical objects in the world and providing a useful description of them'[3]. On WikiMapia, vandalism is defined as 'any deliberate action intended to corrupt information'. WikiMapia's license agreement states that 'you will not post advertisements or solicitations of business; you will not submit false information intentionally; you will not vandalize or corrupt information on WikiMapia'[4]. The project's contributors can report suspicious behaviour on a dedicated forum, which currently contains 983 threads about vandalism[5].

OpenStreetMap is a non-profit volunteered geographic information project started in 2004, focused on the construction and maintenance of a vector map of the entire planet. In this context, 'vandalism is intentionally ignoring the consensus norms of the OpenStreetMap community', and includes copyright infringement, graffiti, use of bots, disruptive behaviour and spamming[6]. Contributors can report suspect cases of vandalism on the project's mailing lists, where incidents are discussed and solved[7]. The

Table 1. Typology of carto-vandalism

| Type	Primary motive	Typical expressions	Physical equivalent
Play carto-vandalism	Frustration with editing tools, boredom	Deletions, simple geometric distortions	Graffiti, damage to public schools and transport
Ideological carto-vandalism	Political communication	Defacement of symbolic places, cyber-bullying against individuals and groups	Political graffiti
Fantasy carto-vandalism	Self-expression, humour	Imaginary and fictional places	Hoaxes
Artistic carto-vandalism	Self-expression	Complex geometries, polygon art	Art graffiti, street art
Industrial carto-vandalism	Indirect profit	Large scale, automated defacement of datasets	Industrial sabotage
Carto-spam	Direct profit	Promotional messages, unsolicited advertising	E-mail and social networking spam
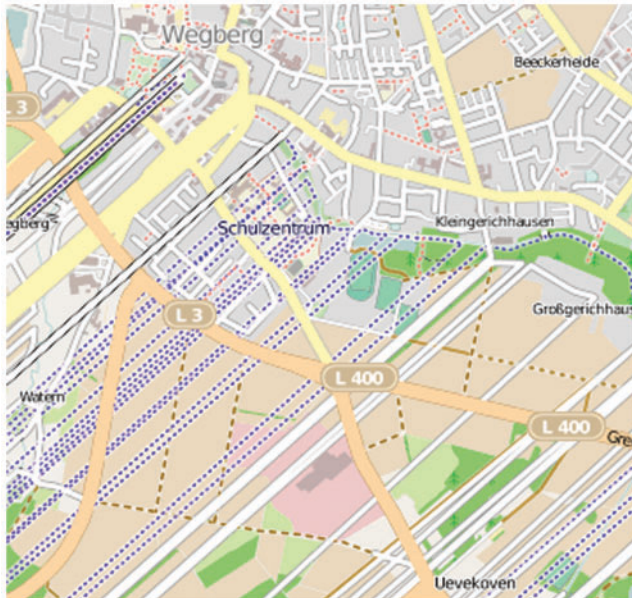
Figure 1. Example of play carto-vandalism resulting in damage to the street network (source: OpenStreetMap)

following sections define in detail each type of carto-vandalism, discussing salient reported incidents.

Play carto-vandalism

To create or modify geographic content, amateur contributors have to use software tools with specific affordances, which are often complex, unclear or poorly documented. Play carto-vandalism arises from human–computer interaction, as part of the playful exploration of affordances (Haklay, 2010b). This type of vandalism is driven by frustration with the editing tools and, as pointed out in the case of school vandalism, by boredom. Acts of play carto-vandalism do not have a clearly intelligible purpose, and they are generally seen as meaningless (e.g. deletion of a river, haphazard movement of points).

Unclear and badly designed interfaces might increase the likelihood of contributors engaging in destructive behaviour. Play carto-vandalism is generally episodic, is particularly frequent among first-time users and is often impossible to distinguish from unintentional damage to the data. For example, OpenStreetMap contributors using *Potlatch 2* editor might not realize that they are editing the main map and not a local copy, and make exploratory changes.

Figure 1 shows an incident of carto-vandalism that has no precise and intelligible purpose, apart from the exploratory interaction with an editor. Similar behaviour can be observed in videogames, in which the exploration of affordances is often accompanied by testing the destructive limits, unintended by the game designer (e.g. killing friendly soldiers or civilians in war games rather than following the game's objective).

Ideological carto-vandalism

Carto-vandalism can be part of political, religious or ethnic conflicts. Vandalism can be driven by overtly political motives. Electoral posters are usual targets of graffiti, through which the images of candidates are ridiculed, distorted and defaced (Whalen, 2013). Urban graffiti are also deployed as markers in a conflict to indicate territorial control (Ley and Cybriwsky, 1974). In these cases, the perpetrator has a clear motive, that is, sending a message to an imagined or real audience. Acts of ideological carto-vandalism include hate speech against target groups through renaming places; edits of contested borders and conflict zones; and cyberbullying against specific users. These incidents can be understood in the framework of cyber warfare, survey by Carr (2011), in which individuals or organized groups perform attacks on digital media following a political agenda.

Military conflicts spill out to volunteered geographic information projects. For example, in July 2012, a group of WikiMapia users repeatedly removed and obfuscated military sites in Syria, acting within the current armed conflict between the Syrian government and the armed opposition (Carpenter, 2013). An alleged member of the Syrian opposition added obscenity to the map, targeting the Alawites, the religious minority to which the Assad family belongs. Another contributor edited the military academy in Aleppo, calling the Alawites 'animals' in the cartographic meta-data. The village Qardaha, home of the Assad family, was renamed as 'home to monkeys'.

Similarly, during the Arab Spring, a user posted pro-government propaganda in Bahrain, while an incident of vandalism was reported in Turkey near the Syrian border. In OpenStreetMap, political carto-vandalism expresses itself in the context of 'tag wars', in which different groups of contributors keep editing the same objects without reaching an agreement (Mooney and Corcoran, 2012). The Israeli–Palestinian conflict manifested itself in disputes over the naming of Jerusalem in the meta-data, and topoynms in the Crimea peninsula in Ukraine created controversy between Ukrainian and Russian-speaking contributors.

Fantasy carto-vandalism

Imaginary places play a key role in grounding fictional worlds in literature, art, and film (Joliveau, 2009). More specifically, Piatti and Hurni (2011) pointed out that 'fictional plots are set along a scale of localisations that range from the realistically rendered, highly recognisable to the completely imaginary' (p. 218). It should therefore not come as a surprise that the imaginations of contributors often find an outlet in creating non-existent places in crowdsourced cartography, resulting in fantasy carto-vandalism.

Contributors conduct this kind of carto-vandalism driven by the pleasure of creating imaginary natural and man-made features, playing the role of town planners and architects, similar to the player in a game such as SimCity (Shepherd and Bleasdale-Shepherd, 2009). Several fictional towns have appeared in crowdsourced cartography. In the German OpenStreetMap, *Lummerland*, a fictional island that featured in works by author Michael Ende, was created and subsequently deleted. Figure 2 shows an example of an imaginary town called *West Harrisburg*, designed by an OpenStreetMap contributor. Along similar lines, a French contributor created *Parfaiteville*, i.e. the 'perfect town.'

Figure 2. Fantasy town in Illinois (source: OpenStreetMap)

Figure 3. Polygon art that depicts an underwater temple in Andhra Pradesh, India (source: WikiMapia)

Fictional places can be created as pranks. In Wikipedia, Danish student Jens Roland created an article about an imaginary municipality, which survived 20 months and was translated into other languages (Nielsen, 2012). As Monmonier (1996) pointed out, cartographers have traditionally indulged in the practice of *trap streets*, which is the creation of small imaginary map features to detect copyright infringement in other providers' maps. Cartographic pranks have also been documented. For example, in the 1970s, Richard Ciacci, an employee in the Public Works Department in Boulder, Colorado, added a Mount Richard to the official county map (Monmonier, 1996).

Fantasy carto-vandalism can also result in the renaming of famous places, when, for instance, a WikiMapia user renamed London and Paris with the name of his small hometown. On OpenStreetMap, Afghan university students assigned fake names (such as 'Hillbilly Hameed') to streets without official names or streets that were subject of naming disputes. Such humorous street names unintentionally ended up in the official Apple Maps (Moore, 2013).

Artistic carto-vandalism

The line between cartography and art has always been fine, and likewise that between art and vandalism. Amateur mappers utilize drawing tools to create, move and connect points, polylines and polygons. The drawing tools can inspire contributors to engage in creative endeavours, deviating from the objective of generating valid geographic information, and moving towards artistic carto-vandalism. The most visible and widespread form of physical vandalism is graffiti and, although most graffiti artists possess dubious merits, the 'street art' of artists such as Vinchen and Banksy constitutes a notable and widely known exception (Lewisohn, 2008).

The idea of drawing massive shapes directly on the planet, only visible from high altitude, is explicitly present in the fascinating geoglyphs found in the Nazca desert, and in some architectural projects, such as the Dubai Waterfront. Since the 1960s, the possibility of impressing art works directly onto the Earth surface has been pursued systematically in the context of 'land art', combining elements of minimalism, photography, sculpture, performance and conceptual art (Tufnell, 2006). A more recent and related field is the socalled 'GPS art', in which the artist traces lines on a map by moving physically on a territory with a tracking device[8].

A typical form of artistic carto-vandalism is 'polygon art', the generation of aesthetically pleasing drawings using mapping tools. Figure 3 shows an instance of polygon art utilized to describe an underwater temple in WikiMapia. Similarly to Banksy's graffiti, as WikiMapia contributors often appreciate polygon art, an area located in the Atlantic Ocean has been created to collect valuable instances of artistic carto-vandalism (Figure 4). This Polygon Art Exhibition Area acts as an art gallery, where the creative output of contributors can be safely observed without compromising the integrity of the geographic data.

Industrial carto-vandalism

Physical and digital vandalism can be performed against an organisation by one of its members, or by a hostile organisation competing in the same economic space. 'Industrial cyber-sabotage' defines the situation where the offender damages data belonging to an organisation. Perceived inequality and unfairness in labour relations drive disgruntled employees against their employers (Fisher and Baron, 1982). Another typical agent of sabotage consists of a competitor that aims at disrupting the target's economic operations, vandalizing visible aspects of its business (Bayuk, 2010). This kind of vandalism can be carried out in a systematic way by organized groups, and is often dissimulated as other types of vandalism. Although industrial cyber-sabotage mainly affects private corporations, allegations of incidents targeted at crowdsourced cartography have recently been put forward. Organisations with high economic stakes in the geo-information market could attack projects to damage their reputation and credibility as information providers.

The 'Mocality affair' started in January 2012 when Mocality, a Kenyan company, reported a case of data theft carried out from machines located in the Google network infrastructure. Subsequently, leading members of OpenStreetMap reported a case of vandalism conducted from IP addresses belonging to Google (Maron *et al.*, 2012). The article stirred a raging and somewhat hysterical debate in

Figure 4.   WikiMapia's Polygon Art Exhibition Area, located in the Atlantic Ocean (57.899S, 159.084W)

the OpenStreetMap community, partly driven by anti-corporate paranoia. Ultimately, the incident seems to have originated from the independent initiative of low-rank contractors to Google in India (later fired), and there is no evidence of the existence of a deliberate cyber-sabotage strategy conducted by Google (Sottek, 2012). Cartographic cyber-sabotage to date is the least likely form of carto-vandalism, but is worth including as it is often discussed by amateur mapping communities.

Cartographic spam

As volunteered geographic information projects rely on public mailing lists, wikis and forums, these spaces are vulnerable to traditional spam messages. Carto-spam, by contrast, is a novel type of spam, consisting of unsolicited messages posted directly at specific locations on a map, in the features' meta-data or in the form of new features. Driven by economic gains and generated in large volumes with the help of bots, carto-spam manifests itself on a spectrum of phenomena, some of which are obvious and some of which are more subtle. 'Obvious' carto-spam occurs in the form of messages bearing no connection with the geographic surroundings, such as hyperlinks to pornographic websites written in the meta-data of a popular building.

At the other end of the spectrum, carto-spam is 'subtle' and consists of targeted advertisement for hotels, shops and real estate, which bear high relevance to the geographic context. In numerous cases, the boundary between neutral description of places and promotional messages is very thin, making its detection challenging, if not impossible. The

same issue arises in review websites, such as TripAdvisor[9], where promotional reviews are generated by the businesses' owners and skew the user ratings, in what has been called 'opinion spam' by Jindal and Liu (2008).

In OpenStreetMap, carto-spammers add specific tags to increase the visibility of businesses, for example by adding the tag *tourism=attraction* to night clubs. The emergence of carto-spam occasionally triggers debates about the scope of acceptable information, e.g. WikiMapia contributors discussed whether 'Joe's shoe repair shop – www.joeshoefix. com' should be considered spam or valid meta-data. In OpenStreetMap, a contributor systematically removed shop names because he did not want the project to become business-oriented. In such cases, divergent views on the utility of geographic information determine different boundaries for carto-vandalism. What is useful for one user can be another user's vandalism.

COUNTERING CARTO-VANDALISM

The success of crowdsourced cartography lies in its ability to harness and coordinate individual contributors towards the production of re-usable digital maps. In this sense, containing and responding in a timely manner to carto-vandalism is crucial to ensuring the integrity of digital artefacts and to keeping contributors motivated. As in other commons-based peer production contexts, crowdsourced cartography faces a participation/quality dilemma, a tension between the need for non-expert involvement and that of high-quality contributions. In order to reduce the societal

harm caused by physical vandalism, two approaches are adopted: repairing artefacts and prosecuting offenders in incidents that have occurred (*ex-post*) and preventing vandalism from occurring (*ex-ante*). In the case of carto-vandalism, legal prosecution is usually not feasible neither desirable; therefore, anti-vandalism strategies focus on detecting and reverting incidents. The only concrete way that a community can punish offenders is by banning them, which does not constitute a strong deterrent.

The issue of geo-information quality is tightly coupled with carto-vandalism. Goodchild and Li (2012) propose three families of approaches to ensure quality. First, *crowdsourcing* approaches are based on the assumption that the more users inspect an area, the higher the quality of the data. Second, *social* approaches rely on collaborative policing, adopting forms of hierarchical control, typically granting special powers to a group of selected users (e.g. moderators, administrators, etc.). Finally, *geographic* approaches aim at data validation through geographic scientific knowledge, and are to date only a theoretical possibility. Currently, volunteered geographic information communities counter carto-vandalism primarily through a combination of crowdsourcing and social approaches, setting up semi-formal mechanisms to police the vast open spaces vulnerable to malicious users, as described in the next section.

Volunteered community involvement and policing

To contain and manage carto-vandalism, amateur mapping communities aim at identifying incidents, in what is essentially a classification problem between valid and damaging changes to an artefact. The manual inspection of changes performed by competent contributors remains the ultimate technique to assess whether a change should be accepted or reverted. Hence, the social mobilisation and coordination of human users is key to identifying and reverting incidents. In order to control and inhibit carto-vandalism, the communities usually ban users, detecting 'sockpuppets', i.e. banned users who create new accounts to keep disrupting the project's activities.

Policing is an essential activity in the digital commons. Williams (2007) observed the emergence of two policing strategies in online 3D platform Cyberworlds. Initially, a 'community involvement' model arose, in which antivand-alism policing is performed on a non-structured basis by common users. After a wave of highly damaging vandalism, a 'volunteered community policing' model was adopted, establishing a structured response through a group of vigilantes with special powers. This pattern occurs across commons-based peer production environments.

In Wikipedia, any user is encouraged to revert vandalous changes through community involvement, using watch lists to monitor articles of interest. Volunteered community policing was initiated through the Counter-Vandalism Unit, which aims to detect, fight and gather first-hand knowledge about vandalism in Wikipedia, with the slogan 'Civility, Maturity, Responsibility'[10]. Members of the unit engage in patrolling, and are rewarded with medals of honour and badges for their efforts. In this context, Kittur *et al.* (2009) pointed out that belonging to a clearly defined group within the community increases the likelihood of

participation in anti-vandalism and other 'good citizenship' behaviours.

To counter carto-vandalism, leading cartographic projects rely on volunteered community policing, coordinated through forums, wikis and mailing lists. In OpenStreetMap, the Data Working Group deals with accusations of copyright infringement, disputes and major cases of vandalism, indicating that 'minor incidents of vandalism should be dealt with by the local community'[11]. Its members have the possibility of banning users only temporarily, while a restricted group of administrators have the power to ban users permanently. The pride in one's local environment functions as an important motivational aspect, encouraging users to patrol familiar areas, tapping their local knowledge to promptly identify and revert incidents.

Being a commercial project, WikiMapia is more centra-lized than OpenStreetMap. However, policing is largely self-organized and relies on gamification to motivate and reward users. The system automatically assigns 'experience points' to editors for types of actions, ranking them in different groups. High-ranking groups, called 'moderators' and 'power users', gain access to advanced map monitoring tools, fewer restrictions and increased powers to ban deviant users.

Given their reliance on social mechanisms, such forms of policing are bound to suffer from the divides that affect volunteered geographic information in general. As Elwood (2010) points out, geo-information about high-income neighbourhoods and tourist destinations tends to be overrepresented, expressing existing divides between urban and rural, high-income and low-income social groups and areas. Analogous coverage biases have been observed in Wikipedia (George, 2007). Another salient divide relates to the technical skills and access to digital technologies that are needed to engage with volunteered geographic information in the first place. In this sense, strategies to counter carto-vandalism are likely to be strongly influenced by such divides, which should explicitly be taken into account.

Furthermore, policing causes social tension within the communities, especially because of the difficulties in classifying carto-vandalism and the hazy boundary between intentional and unintentional damage to the map. Just as in any legal system, anti-vandalism patrols can abuse their banning powers and can wrongly identify and ban a user as a vandal. For example, a WikiMapia user stated: 'HELP! I have been falsely banned as a clone'. The moderator replied 'apparently you edited a few tags that were touched by a known vandal … Your account name resembled a choice pattern of names the vandal had been using lately'. To overcome these limitations, the automatic detection of carto-vandalism has emerged as a complementary approach.

Automatic detection of carto-vandalism

Although human judgement is necessary in most cases to identify incidents of carto-vandalism, automated procedures can provide valuable support. Because of the prominence of the issue and the massive size of its datasets, Wikipedia has attracted research on automatic detection of vandalism, resulting in a number of software tools and classifiers (Adler *et al.*, 2011). After initial efforts with rule-based techniques, machine learning approaches have emerged as being more effective (e.g. Potthast *et al.*, 2008). Indicators of Wikipedia

vandalism are found in character distribution, presence of vulgar words, uppercase/lowercase ratio, semantic relatedness with the edit's context and contributor's reputation. Since 2010, academic competitions have been held to enhance and compare automatic vandalism detection techniques in Wikipedia, using an annotated corpus of changes as the ground truth (Potthast and Holfeld, 2011).

In the context of OpenStreetMap, automatic detection is taking its first steps. Notably, Neis *et al.* (2012) have developed *OSMPatrol*, a rule-based system to detect carto-vandalism in OpenStreetMap. Starting from criteria proposed by the OpenStreetMap community[12], the system classifies users' actions based primarily on the contributor's reputation. However, possibly because of an excessively inclusive definition of rules, the system seems to detect a high number of false positives, indicating edits of experienced users as potential vandalism. *OSMPatrol* confirms the difficulties of clearly discriminating between sub-optimal contributions and genuine carto-vandalism.

Automatic techniques are particularly important to counter carto-spam, which is one of the most threatening forms of carto-vandalism because of its for-profit motive. In recent years, anti-spam techniques have experienced huge advances in the context of e-mails and social networking sites (Heymann *et al.*, 2007). However, spammers respond to new filters by re-engineering their techniques to circumvent automated barriers, resulting in a perverse feedback loop between spam and anti-spam forces. While obvious carto-spam pushing illegal drugs and fake diplomas is easily detectable using traditional anti-spam tools, subtle carto-spam about restaurants, real estate and tourist resorts presents more complex challenges. To automatically detect opinion spam, the sophisticated techniques of natural-language processing, sentiment analysis and social network analysis discussed by Jindal and Liu (2008) need to be combined and tailored to the cartographic domain.

CONCLUSIONS

Carto-vandalism is an emergent area ripe for multi-disciplinary research. This article has provided a discussion of the phenomenon's salient features, motivations and the current approaches adopted to keep it at bay with social and technological detection and control mechanisms. Many open questions and future research directions lie ahead for cartographers, geographic information scientists, social scientists, human–computer interaction experts and human geographers alike.

The typology outlined in this article was based on a direct observation of forums and mailing lists in WikiMapia and OpenStreetMap. To assess the impact and study the processes revolving around the generation and repression of carto-vandalism, more empirical research is needed. Social network analysis and ethnographic observations can be conducted on volunteered geographic information communities, further clarifying the reasons behind carto-vandalism and how communities defend the integrity of the geospatial artefacts. Such research should also be conducted beyond the most studied crowdsourced cartography projects, including smaller projects that might provide original solutions to the problem of carto-vandalism.

To enable the development of machine learning approaches and the empirical comparison between automatic techniques of carto-vandalism, a more extensive corpus of real incidents should be collected, involving the affected communities. To collect instances of carto-spam, the idea of 'honeypots', i.e. spaces designed to be particularly attractive to spammers, could be adapted from the context of social networking websites and applied to volunteered geographic information. Existing counter-carto-vandalism techniques are *ex-post*, aiming at identifying incidents that have already occurred. By contrast, *ex-ante* approaches of prevention have been ignored. Human–computer interaction principles to design volunteered geographic information online spaces can draw on the architectural ideas developed in crime prevention through environmental design, which aim at designing criminogenic factors out of the built environment (Cozens, 2008). Furthermore, as much play carto-vandalism is caused by the interaction with complex editing tools, research in geospatial human–computer interaction is needed to identify design principles to facilitate volunteered geographic information production and monitoring, preventing, and not only repairing carto-vandalism incidents. Relevant ideas can also be sought in the area of videogame design. As Shepherd and Bleasdale-Shepherd (2009) point out, many modern videogames have interfaces to interact with complex geographic information, and provide useful ideas to improve the often unsophisticated mapping tools used by amateur mappers.

The study of carto-vandalism can help understand the issue of the long-term sustainability of crowdsourced cartography, often mentioned as one of its critical weak points (Dodge and Kitchin, 2013). The geospatial digital commons are threatened by a peculiar form of the so-called 'tragedy of the commons'. The tragedy of the physical commons occurs when the behaviour of individuals, driven by their self interest, ultimately leads to the depletion of a finite resource, such as the atmosphere, the rainforest, and the reserves of fossil fuels. As Jayaraman (2012) has suggested, the digital commons are affected not by the overexploitation that plagues the physical commons, but by *underexploitation*: the tragedy arises precisely when commons-based peer production projects lose participants and their labour, and the digital artefacts see their utility decreasing, ultimately leading to their disappearance. In his discussion of Wikipedia, George (2007) argued that, to avoid the tragedy in the long run, complex governance is needed, carefully managing vandalism and incentivizing high-quality contributions.

This issue is of particular relevance for cartographic artefacts, which suffer from rapid obsolescence. Every map is by definition a historical map that reflects a past state of affairs and needs updating. To keep a map alive, constant and systematic efforts are necessary, keeping the gap between the map and the territory constant. It is possible to imagine that once a commons-based project has lost its initial thrust and popular appeal, carto-vandalism can damage a dataset's value irreparably, leading to the project's eventual demise[13]. To date, no survey exists of the life expectancy of commons-based peer production projects. Such research directions around carto-vandalism might offer insights on the issue of maintainability and help identify important factors in the

survival of volunteered geographic information projects amidst turbulent and unstable flows of contributions.

BIOGRAPHICAL NOTES

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NOTES

[1] In 1934, Benito Mussolini commissioned and supervised the construction of a monument consisting of five 'imperial maps', overlooking the *Via dei Fori Imperiali* in Rome. The first four tablets represented distinct phases of the expansion of the Roman Empire, while the fifth showed the borders of Fascist Italy, inviting a comparison between the Roman Empire and his own regime.

[2] For a discussion of the problematic notion of 'online community', see Williams (2006), pp. 14–17.

[3] http://wikimapia.org/docs/About_Wikimapia

[4] http://wikimapia.org/terms_reference.html

[5] http://wikimapia.org/forum

[6] http://wiki.openstreetmap.org/wiki/Vandalism

[7] http://lists.openstreetmap.org

[8] http://www.gpsdrawing.com

[9] http://www.tripadvisor.com

[10] http://en.wikipedia.org/wiki/Wikipedia:CVU

[11] http://wiki.openstreetmap.org/wiki/Data_working_group

[12] http://wiki.openstreetmap.org/wiki/Detect_Vandalism

[13] In this sense, the British Library-funded UK Web Archive acts as a graveyard for dead websites (http://www.webarchive.org.uk/ukwa)

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