Chapter 5

State of the Art

5.1 Participatory GIS for Development

As discussed in Chapter 4, PGIS researchers have used geospatial technology since the 1990's to support communities in developing contexts for purposes such as making tenure claims, environmental defense against petroleum and other extraction industries, as well as for community planning purposes. This focus on underpriviledged and excluded communities is a natural extension of the PGIS belief that, as Giacomo Rambaldi put it, 'GIS, spatial data, and maps produce and negotiate politics and power relations', and their potential to 'foster participatory decision making processes.' [67][57] Perhaps most importantly, such efforts promise to look beyond traditional technologies and systems of knowledge. This echoes Sarah Elwood's hope that alternative GIS movements 'could incorporate diverse forms of spatial knowledge and promote multiple epistomologies'. [27]

Examples of adoption of geospatial practices amongst vulnerable communities are widespread, incorporating a variety of techniques including the use of handheld GPS devices to delineate ancestral boundaries, traditional pen-and-paper drawing on terrain maps, and even aerial photos from flyovers in lightweight aircraft. However, critics of PGIS practice point out that despite the emphasis on inclusion in the mapmaking process, final map processing is often outsourced to 'real' GIS experts, subverting the intent to involve participants directly in the production of their own maps, and building dependence on outside entities. While in some cases, local mapmakers have been successfully trained to use traditional digital GIS tools, obscure interfaces and basic internet access and literacy issues often present substantial challenges to this approach. [63]

Also concerning is the persistence of a detached anthropologic attitude, where researchers distance themselves from the data they are 'capturing'. In many PGIS publications there is a definite note of surprise that 'indigenous' communities, whether in sub-Saharan Africa or simply in communities without a high degree of technical fluency, could author good maps or manage geospatial data. The excitement over the moment of cartographic understanding which the following narration by Robert Chambers recounts is tempered by the condescension it implies:

> It was also in 1988 in an AKRSP (India) RRA training... that a headman, asked to present to the villagers the map the outsiders had draw, had difficulty until he turned it "upside down", which was the way he and the villagers saw their village . . . . We

were teetering on the brink of learning that "They can do it". [16]

PGIS researchers have not been insensitive to these issues; Chambers himself points argues that 'Many ethical issues present troubling dilemmas, and lead to overarching questions about empowerment and ownership. Questions to be asked, again and again, are: Who is empowered and who disempowered? And, who gains and who loses?' [15]

In practice, there is a question of formats: while for many communities a paper map would be the ideal end product, many cartographers feeel the need to produce digital maps in a variety of formats, such as shapefile, Keyhole Markup Language (KML), Web Map Service (WMS), etc. This raises the question of who the intended audience is — the funding agency, perhaps, or the PGIS academic community, or even the blogosphere. These are valid considerations; if the mapmaking is intended to help a community to communicate with official entities, i.e. to influence a cartographic power relation, a digital end product may help to 'translate' local knowledge into the relevant language of power.

To be fair, outsourcing of final map processing may seem like the only way to produce a completed map without the challenging prospect of training local participants in the use of GIS software. It may also be a means to build a better and more integrated relationship between the local community and those governmental entities they are attempting to communicate with. However, such benefits are speculative at best, and Peter Poole argues that such an advantage 'has yet to be widely demonstrated', citing examples in Suriname and Venezuela. [63]

Such difficulties suggest that a broader reconceptualization of GIS tools and practices — which adapt geospatial interfaces and tools in order to lower barriers to entry — may allow vulnerable communities more direct control over their geodata, its publication and use. The Grassroots Mapping project proposes an alternative geospatial workflow which echews expensive handheld GPS devices and complex software, in favor of direct photographic imaging. Design decisions have promoted intuitive and user-friendly interfaces (see the discussion of 'rubbersheeting' in Section 6.2.3) over automated 'black box' approaches. While the workflow I propose does depend upon internet access, it does so with the awareness that the ability to produce digital output is an important part of participation in broader geospatial discourse. Many governmental and aid organizations, and of course members of extraction industries, rely upon and communicate with GIS tools and formats, and in order to participate in decisionmaking with such entities, digital mapping is often a prerequisite.

5.2 Web mapping

With these challenges in mind, it is especially exciting that recent advances in web-based digital mapping tools have dramatically broadened access to geospatial technologies. Some degree of mapmaking ability has become commonplace to the internet-connected public since the advent of highly user-friendly 'slippy map' interfaces such as Google Maps. The release of the Google Maps API in the summer of 2004 was an important milestone to would-be cartographers, allowing users to modify and repurpose Google's web map services for new purposes. Among early applications of the API was the GMaps Pedometer, which would output the length of a path you walked, along with how many calories you burnt. [29] From the frivolous to the essential, this means of mapmaking has become widespread and relatively easy. However, many would argue that this is not mapmaking at all; most of the users of Google Maps do not edit the underlying map data, but overlay points, lines, and polygons **on top of** Google's proprietary data — an obscure but important fact which has direct bearing upon a broader participatory cartography.

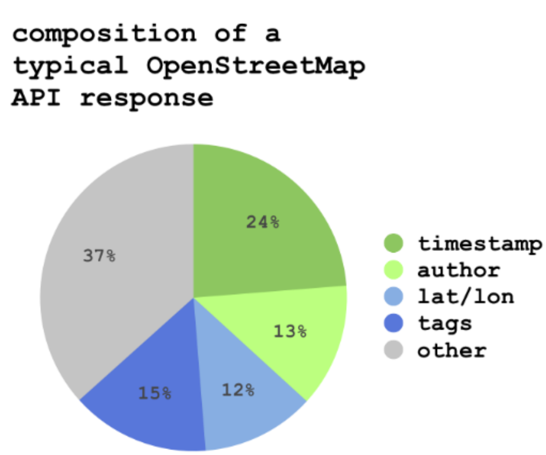
5.2.1 Google Maps and proprietary data

In fact, not only Google Maps, but the vast majority of the online maps are based on the relatively static base maps made available by larger organizations. Google and other providers of map data publish these maps as collections of small image 'tiles'; JPG or PNG images of 256 by 256 pixels, which are rendered ahead of time and cached. These are served using Apache or another conventional web server. The main benefit of this technique is that it serves map data as a set of regular image files; a standard and highly optimized means of distribution. These are re-assembled in the browser into an apparently continuous map, and as the user pans or 'slips' around, new tiles are transferred to maintain the illusion of continuity.

A second reason for the use of map tiles is that it is quite difficult to reconstruct the original discrete vector data set from map tiles; in this respect they are similar to compiled code. Google and other commercial map vendors do not share their point, line, and polygon data, nor do they make metadata such as labels or land use markers available. Distributing tiles gives them a degree of control over what source data they choose to release.

Distributing the underlying data used to generate these tiles conflicts with these companies' business models: such data is valuable intellectual property. The tile-based rendering system strips the map of its metadata, making a local, or personal, critical, or revisionist interpretation quite difficult. Tiles are immutable — they contain no information about authorship, no hyperlinks, and in order not to crowd a given tile, each one displays only a selection of available data for that corresponding area of the world. Though originally motivated by technical limitations, the near-universal use of tiled maps has become a form of exclusion, allowing large organizations to control maps in spite of the common rhetoric that the Google Maps API has enabled a more open, participatory cartography.

Open data projects such as OpenStreetMap, the 'wiki map of the world', do just the opposite — like the open source software projects they took inspiration from, they publish the entire dataset as coordinates, semantic tags, polygons, and most importantly, time and authorship data. Though most maps using OpenStreetMap data are tile-based, the underlying data is freely available from the project's website — anyone with enough disk space can download the entire planet's worth of data (over 200 gigabytes when loaded into a database) and create their own maps. In that dataset in particular, authorship data actually outweighs its geometric counterpart. Perhaps even more tellingly, historical data — for areas of the map which have been overwritten — occupy more



storage space than current data. This suggests that authors have challenged each other's data more than they have added new data to unmapped areas. [81]

5.2.2 OpenStreetMap

OpenStreetMap.org, taken as an open-source software project, a database of open geodata, and a community of volunteer mappers, represents one of the best examples in recent years of the *neogeographic* response to PGIS. That is, without explicit ties to the PGIS movement, or reference to the movement's two decades of literature and research, OpenStreetMap (or OSM, as it has become known in neogeographic circles) has attempted to meet many of the same goals since its founding in 2004. OSM encourages volunteers around the world to contribute to a single, shared digital map and corresponding map database. [17]

In many ways it has met with wild success, and the size and detail of the OSM map database is formidable. In July 2010, the project included over 700 million points, making up some 56 million polygons, all contributed by more than 280,000 users. [60] However, participants are overwhelmingly European and American, and tend to be wealthy due to the emphasis on internet connectivity and the use of GPS devices to produce new map data.

In fact, the OSM data collection strategy relies most heavily upon three sources. First, existing municipal and public domain databases make up an enormous part of the available data; the TIGER database produced by the US Census increased the size of OSM by a factor of twenty. [83] Second, tracing of satellite data with the Potlatch, JOSM, and other tools to extract vector data from rasters plays a large role, especially in areas with few local participants. This technique was used in the OSM Gaza project to map all of Gaza using a satellite dataset purchased for $5,000 from DigitalGlobe using donations during the Gaza war in late 2008. [42][17] While convenient in that it does not require mappers to actually travel to the places they are mapping, it does not actively involve residents of an area in the mapping process, and sufferes from many of the shortcomings which inspired the PGIS movement.

Finally, much of the OSM database was created by individuals carrying GPS devices to record GPX tracks, or collections of latitude/longitude coordinates. These are later uploaded, annotated and merged into the main OSM database using tools such as JOSM. This is the preferred means of collecting data because of its high accuracy, its emphasis on firsthand mapping, the clear legal ownership of the data, and because of the implicit belief among many OSM participants that better maps are made 'on the ground'. This belief is supported by the 'on the ground' policy stated explicitly in the OpenStreetMap wiki, as is discussed in Section 3.2.

5.2.3 The modern open-source geostack

Another interesting aspect of OpenStreetMap is that it represents a deployed and working combination of many of the premier open-source mapping tools available today. It makes use of OpenLayers, a web browser-based framework for displaying raster map tiles using JavaScript. Tiles are produced using Mapnik, the popular open-source tile renderer. An array of other open-source utilities are used to create, edit, translate, import, and export the data. The Grassroots Mapping project, and especially the Cartagen Knitter, can be seen as an opportunity to augment this geostack with an equally open means of capturing source imagery and integrating such data into the open-source

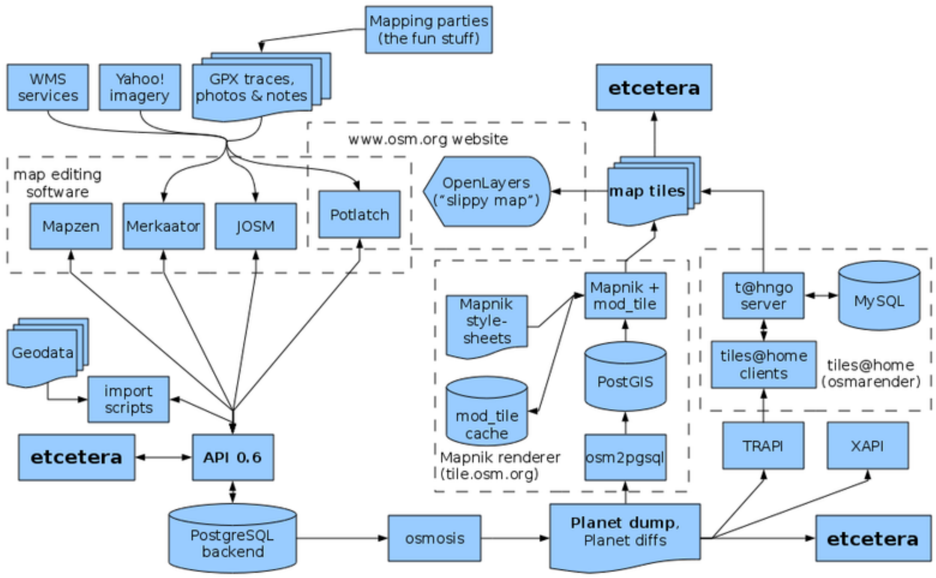


Figure 5.1: A system diagram of the OpenStreetMap, courtesy Iván Sánchez Ortega. The red box which I have added to the upper left represents how the Grassroots Mapping project may integrate with this system.

workflow.

5.2.4 Humanitarian OSM Team

An offshoot of the OpenStreetMap project known as Humanitarian OpenStreetMap Team (HOT) was started in late 2009 by Mikel Maron, a map programmer and board member of OpenStreetMap. Positioned in direct response to the need for maps in areas of humanitarian crisis, Maron has organized members from the technology community to visit crisis zones such as Port-au-Prince as well as a long-term presence in Kibera, the largest slum in Nairobi, Kenya. HOT uses the same tools as the wider OpenStreetMap community, and either runs a separate instance of the OpenStreetMap server and database, or directly uploads the data to the main OpenStreetMap.org service. [59]

OSM Gaza

HOT's first project, a volunteer effort to map the Gaza Strip during the 2008-2009 war between Israel and Gaza, relied on Yahoo Maps and Digital Globe satellite imagery. Over seven days, OpenStreetMap volunteers traced the satellite imagery in order to produce a more accurate, more up-to-date map, and with assistance from JumpStart International, the map was available online and for download with no copyright restrictions. [17] This emphasis on placing map data (not just rendered maps!) in the public domain was intended to enable the widest possible uses of the information, on both a technical and legal basis. In order to preserve this legal status, the OSM Gaza dataset was published separately from the main OpenStreetMap database, though in accordance with its liberal licensing, a copy was uploaded to OSM as well. Building on the success of the OSM Gaza project, HOT went on to collaborate with a variety of organizations in countries like India, Kenya, and Georgia, all using the OpenStreetMap toolset (see Section 10.1.2).

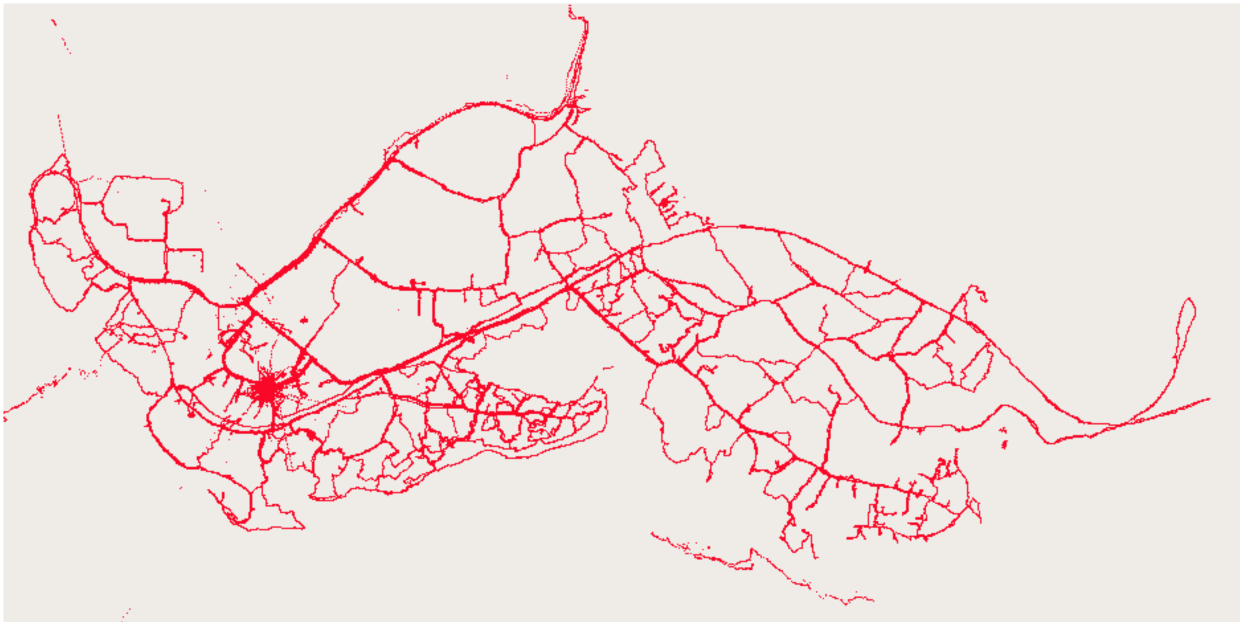


Figure 5.2: GPX traces collected from GPS units over three weeks of mapping in Kibera. http://www.flickr.com/photos/mikel_maron/4143021346/

Two projects by HOT stand out as their most ambitious and influential. The first, called simply Map Kibera (http://mapkibera.org), produced a map of the famous Kibera slum in Nairobi, Kenya, in collaboration with several local organizations. This project differed from earlier HOT projects in that it relied primarily upon local participants using hand-held GPS units to produce the map, as well as with paper-based map annotations using the Walking Papers system developed by Michal Migurski of Stamen Design. With a specific mission to engage in the sociopolitical aspects of cartography, Map Kibera is much more explicit than OSM Gaza in its agenda and the needs it addressed. It also represented a shift away from remote mapping by means of tracing, towards a model which relied more heavily on local expertise and familiarity with the site. In this sense it has much more in common with the Grassroots Mapping project; both attempt to empower local communities by buildling local capacity and ceding control over the mapping process to local individuals and organizations.

The second project of note is the mapmaking work done in the aftermath of the January 2010 earthquake in Haiti. While the full extent of crisis mapping work in Haiti is beyond the scope of this document, it is important to note that much of the work of aid organizations in the disaster was supported by OpenStreetMap data — data which was traced from satellite imagery. Mikel Maron writes:

> The have been at least 400 OpenStreetMap editing sessions in Haiti since the quake hit. Mostly tracing Yahoo imagery, and gleaning information from old CIA maps. We also just received permission to use GeoEye imagery acquired post-event that will allow us to tag collapsed buildings.

[45]

This dataset has proved essential, not only to the open geodata community, but to larger traditional organizations who were unable to find better maps, prompting some to refer to the Haiti disaster as a 'sea change' in the widespread acceptance of crowdsourced geodata. Alan Glennon points out that 'all the United Nations agencies acting on the ground in Haiti used OpenStreetMap for their print maps' [30]

This reliance on satellite imagery for crisis mapping demonstrates its ability to rapidly produce maps, but neglects the importance of building local mapmaking capacity and infrastructure. The initial Haiti maps were made entirely without the participation of local residents, due to the urgency of the situation, not to mention internet access issues and the overwhelming willingness of foreign volunteers to help produce maps. As discussed in Section 4.4.1, in the weeks and months following the initial disaster, access to satellite data would prove to be a bottleneck not only for local control of mapmaking efforts, but for everyone involved in the crisis mapping response. Open licensing of new imagery would allow for damage assessment and monitoring of the humanitarian crisis that has unfolded in the wake of the disaster.

5.3 Orthorectification

These difficulties highlight the need for an alternative and more inclusive means for sourcing aerial imagery, not only for local communities and activists, but for broader efforts like the crisis mapping and open geodata movements. With this in mind, this section will focus on existing approaches for capturing and processing aerial imagery. While there are a diverse range of approaches to participatory mapping, several prior works have focused, as I have, on building free or widely available tools for orthorectifying aerial imagery as a means to produce and publish mapping data. Their uses range from stitching aerial imagery captured from hobby-levelremote control aircraft to rectifying historical printed maps in order to digitize their contents.

5.3.1 Map Warper

Perhaps the most ambitious project of this type is the Map Warper software written by Tim Waters, Schuyler Erle, and Shekhar Krishnan, as part of their effort to 'crowdsource' the digitization of the New York Public Library map archive. [82] The tool invites volunteers to orthorectify maps by matching Ground Control Points, or GCPs, between a source image and a reference map, and using an automated affine warp (based on the Geospatial Data Abstraction Library (GDAL) open source tool) to produce a composite map.

While designed for warping archival maps onto a vector dataset, namely OpenStreetMap, the tool can be used to warp aerial imagery onto satellite data. This is achieved by inserting a new layer into the reference map pane, which is implemented in OpenLayers. The resulting warped image can be downloaded as a GeoTIFF or accessed as a standards-compliant WMS layer. A more complete discussion of this tool and its applicability toward grassroots aerial mapping can be found in Section 7.2.

5.3.2 GonzoEarth and manual stitching with Adobe Photoshop

One of the leading practitioners of low-cost mapmaking today is Stewart Long and his one-man company GonzoEarth, which provides 'applied neogeographical techniques for on-demand mapping' [39]. Long is responsible for such impressive maps as the 2009 map of Burning Man, published at a 2 cm resolution[1]. This map was warped onto a lower resolution base map, blended, and output as a BigTiff image, surprisingly using Adobe Photoshop CS4. The image was then reprojected and saved as a GeoTIFF using the open source GDAL package. Long's use of Photoshop extends to all his mapping work, due to its ability to 'make dynamic selections, transformations, and stitching' including layer merging and flattening. [39] While observing his process, I noted that he would repeatedly return to earlier images in order to adjust them iteratively. GonzoEarth maps are among the best available in that they are seamless and consistent, and Long has both patience and a unique intuitive grasp of the process. Careful observations of his work have played a major role in the design of the Cartagen Knitter, described in Section 6.2.2.

The imagery for the Burning Man map was taken from a helium balloon by Jack Alderson, but Long also captures imagery by using a lightweight and relatively inexpensive remote control airplane called the Easystar, sold by the German company Multiplex. A small Canon camera is inserted into the cockpit and a hole is cut in the belly of the plane through which the pictures are taken. Long can fly the plane at up to a half-mile away, steering manually with a 2.4 Ghz transmitter and can capture imagery at hundreds of feet in the air. The plane can remain in the air for up to an hour.

5.4 Aerial imaging with low-cost tools

Due to the need for cheap and up-to-date imagery, a major part of the Grassroots Mapping project has been the design and use of low-cost platforms for capturing images of the ground from above. The use of kites and balloons to raise consumer-level 'point-and-shoot' cameras has allowed participants to capture images of sites of interest at minimal cost. A Grassroots Mapping Kit can be assemnbled for less than $150. This would not have been possible without building upon the long tradition of Balloon Aerial Photography (BAP) and especially the research and careful documentation by more recent innovators in the field. While balloons have been used as a platform for photography since Gaspard Felix Tournachon's first attempts in 1858 [80], publications throughout the mid-1990s and into recent years by researchers such as Lee Vierling, A. Buerkert, Michiru Miyamoto, and many others, have es-

Figure 5.3: Maron jokingly referred to this experiment in KAP as the 'first Palestinian spy satellite'. [41]

[1] View the map online at GigaPan.org: http://gigapan.org/gigapans/46290/

tablished a diverse set of techniques and use cases for such imagery. Similar examinations of KAP techniques by James and Susan Aber and others, have led to the coining of the term **Kiteography** — defined by Vierling as the use of KAP for 'making large-scale topographic maps, based on photogrammetric principles.' [80] In general, the existing research has emphasized the low cost and high resolution of resulting data, and most researchers have focused on its applicability to environmental assessment. [2][1][51][10]

Of particular interest is Eric Wolf's thesis on the use of BAP for 'necrogeography', or the mapping of cemeteries, where he examined the accuracy and precision of various approaches to orthorectification.[2] as well as in comparison to high resolution readings from a differential GPS. Wolf has been generous in contributing advice and even equipment to the Grassroots Mapping project. Also of note are Mikel Maron's attempts to use kites to produce maps in Palestine [41] with KAP techniques. However, few of these prior works have addressed the challenges in facilitating the adoption of such tools by non-technical participants, or in their potential to provide high quality map data to those without proficiency in GIS technologies.

5.4.1 DIYDrones.com and the T3 competition

One notable use of autonomously piloted model aircraft which holds much promise for the future of low-cost mapping is the 2009 DIY Drones Trust Time Trial (T3) event, where enthusiasts of autonomously piloted model aircraft were put through a series of successively more difficult tasks such as flying a complex route. The competition's Round 4 event, entitled 'Map a quarter-kilometer!' challenged participants to photograph a 500 meter square from their aircraft, and to submit a KML of the route as well as a stitched map of the target area. Seven entrants from five countries completed the round, using a variety of autopilot systems and airframes. [6] The complete costs of such kits ranges from approximately $1,000 upwards, but as the cost of this type of equipment drops, this may be an increasingly viable means of capturing aerial imagery. At the same time, it is important to remember that these are essentially adaptations of military technology, and local context must be taken into account — in many places, such as the West Bank, remote controlled aircraft may be unwelcome or perceived as threatening both by local communities and regional military or law-enforcement agencies.

The techniques I have refined in my own work have built primarily upon precedents in balloon and kite photography. I have striven to further simplify the assembly of a working kit, and attempted to devise methodologies for effective teaching of the techniques. In addition, I have worked with others to push the limits of balloon and kite mapping in terms of altitude, resolution, speed of capture, and ease of image processing and map publication. These improvements will be discussed in the following chapter.

[2] See Section 6.2.2 and Section 9.3.1