Collaborating with Bots and Automation on OpenStreetMap

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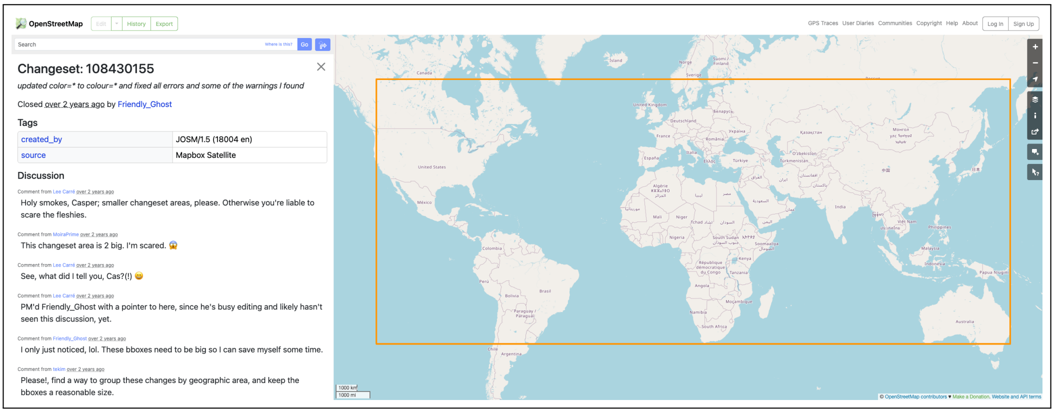

Fig. 1. OpenStreetMap is a collaborative effort to build a map of the world. In addition to human editors, bots and scripts also are used on the platform. This can lead to tensions and conflicts. In the example shown here, a bot has globally changed tag spelling and created a very large changeset (#108430155). This resulted in a lengthy discussion on the changeset itself, but also in other places, like the mailing lists.

OpenStreetMap (OSM) is a large online community where users collaborate to map the world. In addition to manual edits, the OSM mapping database is regularly modified by bots and automated edits. In this paper, we seek to better understand how people and bots interact and conflict with each other. We start by analysing over 15 years of mailing list discussions related to bots and automated edits. From this data, we uncover five themes, including how automation results in power differentials between users and how community ideals of consensus clash with the realities of bot use. Subsequently, we surveyed OSM contributors on their experiences with bots and automated edits. We present findings about the current escalation and review mechanisms, as well as the lack of appropriate tools for evaluating and discussing bots. We discuss how OSM and similar communities could use these findings to better support collaboration between humans and bots.

CCS Concepts: • **Human-centered computing** → *Collaborative content creation*; • **Computing methodologies** → *Intelligent agents*.

Additional Key Words and Phrases: OpenStreetMap, Bots, Automated edits, Automation, Collaboration

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1 INTRODUCTION

Large-scale collaborative projects rely on a combination of contributions by human editors and those performed automatically through bots and other forms of automation. Examples of such projects are Wikipedia, OpenStreetMap (OSM), Open Food Facts, iNaturalist, but also many Open Source software development efforts. Just OSM has users make over 4 million daily map changes[1], working towards the goal of mapping the world. Due to the large scale of OSM and similar projects, keeping their content updated and consistent can be challenging. For example, if a street is renamed, somebody needs to go into OSM and update all sections of that street as well as the addresses of buildings next to it. In contrast to other projects, OSM strongly values local community and ground truth and thus such updates are desired to occur through those means. Yet, tasks like this can be error-prone, tedious, or simply infeasible due to the large number of objects affected by a change. Hence, OSM also allows users to automate such tasks through an API—an approach also followed by all the other projects mentioned above. Users can then write bots and scripts for automated edits in order to make large changes to the map, such as revising how objects are tagged or importing large amounts of external data. The collaboration of human users with such automation tools has been shown to lead to better results and effectiveness than either side working on their own [13, 37, 62].

Yet, while automation has many advantages for large-scale projects, this does not come without challenges. For example, prior work has highlighted the additional work introduced by automated bots on Open Source software projects. This includes, for example, introducing additional noise due to a high frequency of bot actions [65], an impacted sense of community [55], and frictions between newcomers to Wikipedia and anti-vandalism bots [26]. The moderation of contributions through automation has been labelled as 'algorithmic governance' [45], in which the developers of bots or automation hold extensive power [15, 39]. In OSM, the main focus of this paper, previous research has described how automated data imports can boost contributor activity and bring in new users [67]. Yet, the OSM community has also shown concern around the use of automation and has devised rules and guidelines on the use of automated edits[2]. These examples highlight the communities' understanding of the risks and challenges of using these tools, while also indicating the inherent value that can be obtained through them. Despite this, little is known about the expectations and wishes of community contributors and maintainers in using and integrating bots into collaborative work. A better comprehension of contributor expectations can inform the development of practices and tools that reduce conflict, democratise access to automation, and contribute to the goals of collaborative communities.

To better understand the requirements of automated editing tools, we set out to investigate the challenges currently experienced in the OSM community and the desires for future developments. An increased understanding of a community and its values has been shown to be critical in advancing automation support [56], with prior work highlighting various gaps between current automation practice and desired outcomes. First, we qualitatively analyse historical mailing list conversations on the topic of automated edits. Subsequently, we use the insights obtained from our analysis to conduct a survey in order to solidify our understanding of challenges in automated collaboration and identify opportunities for future development.

We find that while there are strong benefits of using automation, it also conflicts with the OSM community's desire for consensus and local engagement. Here, locality is a key distinctive characteristic from other collaborative platforms—in which different (geographic) communities are more formally separated and less likely to interact with one another. Furthermore, automation influences the power dynamics on OSM, giving some users a greater impact on how the project is

[1]Per https://wiki.openstreetmap.org/wiki/Stats.
[2]See https://wiki.openstreetmap.org/wiki/Automated_edits.

developing. As automation can easily cross geographical and community boundaries, automation has the potential to instigate conflict when these communities differ in their mapping and labelling practices. Our survey participants provide further insights into how contributors respond to these challenges, including how issues with bots are escalated. They also demonstrate a need for tools to inspect and moderate edits performed by bots and scripts to (1) help democratise the development of OSM, and (2) build trust in automation. We relate our findings back to larger issues around bots and automation in collaborative communities and provide key takeaways for OSM and similar projects. Given the benefits of bots and automation, our insights also offer value beyond the OSM community, with an increasing number of citizen science communities growing beyond a scale manageable solely through manual edits.

2 RELATED WORK

A growing body of work in HCI studies online collaborative projects, often labelled as either citizen science projects or, more broadly, crowdsourcing efforts [49]. In this paper, we focus specifically on the use of bots and automation in collaborative projects and how human contributors interact with these technologies. Here, we first outline prior work describing motivations for participation and challenges faced in online collaborative projects, with a focus on OSM. Following, we describe prior work on automated solutions introduced in the context of online collaborative projects, including OSM, Wikipedia, and GitHub. Finally, we discuss the benefits and identified challenges concerning the use of automation in online collaborative contexts.

2.1 Participation in Collaborative Projects

People's motivations for participating in collaborative projects have been a focus in research [5, 10, 11]. For OSM contributors, Budhathoki and Haythornthwaite identified an appeal to the greater good, affinity with open-source and geographic knowledge, and community participation to be the primary motivators [5]. Furthermore, casual mappers are motivated more by the general notion of free data availability while more serious mappers are motivated more by the community and continued learning.

Other work on collaborative projects has focused on dealing with malicious actors in online collaborative projects [12, 32, 49]. Ferreira et al. characterised incivility in the discussion of open source code review [12]. Their analysis of 1,545 emails on the rejection of code changes as posted on the Linux Kernel mailing list identified that two-thirds of non-technical emails contained uncivil features. This includes name-calling, impatience, and general frustration. Jhaver et al. studied the responses of Reddit users after their uncivil posts were removed by moderators [32]. Their results show that users who had either read the community guidelines or received an explanation for the removal of their post were more likely to perceive the removal as fair. These works highlight both the diverse reasons why people contribute to online collaborative projects, as well as the challenges encountered when these people interact with one another.

2.2 Collaborative Geographical Projects

Online collaborative projects face a number of challenges, including the non-uniform distribution of efforts and contributions within a project, a lack of diversity among contributors and contributions, and rapidly changing requirements and expectations in emergency scenarios. Here we specifically focus on the implications of these challenges for projects focused on geographic information. The lack of diversity of both contributors and contributions within this domain has been the subject of multiple studies. Quattrone et al. studied the characteristics of OSM contributors and found that cultural factors (e.g., power distance) as well as GDP play a role in the number of edits made, with more data contributions in richer countries [50]. Urban areas have furthermore been found to have higher quality and quantity of data compared to rural areas, where the ratio of imported data is higher [33, 50]. Choe et al. investigated factors affecting conflict between mappers on OSM [7]. Their results of a Delphi survey show aspects such as clashing opinions between community subgroups and negative mapping behaviour as primary reasons for conflict. At the level of individual contributors, prior work has highlighted that women contribute less to OSM than men [9]. Similar data has been found in Wikipedia, with women making up an estimated 15–20% of the editors [2]. Highly relevant to our work, Das et al. highlight differences in the way bots are used by women and men [9]. Their results show that male editors had a higher proportion of bot-based contributions than female editors. Based on these findings, Das et al. suggest that "*the male influence on OSM content further increases when we consider bot activity*", highlighting the prominent role bots play in OSM.

An important element of consideration within the context of localised contributions is the degree of data produced by 'non-locals', who contribute extensively to local mapping efforts [29]. According to a cross-platform analysis from Thebault-Spieker et al. across OSM, Wikipedia, and eBird, many contributions originate from people that are actually not located in the area of their contribution [59]. The authors highlight that this has various implications for the collection and use of this data, stating that having physical access to a region is likely to boost one's knowledge of it. Thebault-Spieker et al. also suggest that known locations may attract extensive contributions—something they refer to as 'regional boosterism'—instead of the locations where edits are needed most. Mashhadi et al. investigated which factors affect the non-uniform geographical distribution of contributions [44]. Their analysis of the Greater London area highlights that population density and distance from the centre, for example, correlate with the number of 'Foursquare check-ins'.

Finally, prior work has outlined the unique challenges which arise during mapping efforts in crisis scenarios [36, 47]. The immediate need for up-to-date geospatial information gives rise to alternative approaches to automation and collaboration. For example, Maas describes the use of Facebook usage data to provide information on the physical whereabouts of individuals [43]. During the 2010 Haiti earthquake, accurate and timely geospatial data, as provided through rapid collaborative mapping efforts, greatly supported humanitarian aid organisation [36]. The high speed of new contributions and edits within a confined geographical area resulted in 'map congestion', in which coordination of work was highly challenging [47]. Crises events also attract new contributors and Kogan et al. highlight that these contributors miss the knowledge of the (unwritten) rules of contributing to the platform [36]. Existing patterns of collaboration (e.g., directly editing others' mistakes rather than seeking contact) are not experienced as helpful by these users. Palen et al. contrast the efforts and impact of OSM across two separate crisis scenarios, the 2010 Haiti earthquake and the 2013 typhoon Yolanda. Their results highlight how OSM has (1) implemented both organisational changes, such as the formation of a Humanitarian OSM Team, as well as (2) developed technical solutions, such as an enhancement of simultaneous editing within the same geographical area, to better support high tempo mapping efforts. Prior work on collaboration dynamics on Wikipedia has similarly identified 'bursts' in activity [34], for example following breaking news developments.

While bots and automated edits have been proposed as a solution to overcome some of the challenges faced in OSM and similar projects (e.g., low coverage of rural areas), it is apparent that bots and automated edits have also introduced new challenges. In this paper, we set out to understand the experiences of OSM contributors in relation to bots and automated edits.

2.3 The Promise of Automation

To overcome some of the challenges encountered in online collaborative projects, automation has been explored across different projects and communities. Automation typically takes the form of bots, which autonomously scan for issues that need addressing and perform the required action.

Another type of automation is automated edits, in which a system performs a set of actions across a larger part of the dataset. Classifications of the various roles that bots and automation can play have emerged, such as from work by Zheng et al., who studied the roles bots play on Wikipedia [69]. Based on a classification of 1601 active bots, they identify nine distinct roles: generator, fixer, connector, tagger, clerk, archiver, protector, advisor, and notifier. Despite the large variety of bots on Wikipedia and their extensive number of automated edits, prior work suggests that conflict between bots is relatively rare [17]. A smaller-scale study characterised 48 bots in open source software projects on GitHub and identified a variety of bot tasks, including reminding contributors to sign a Contributor License Agreement, notifying of integration failures, and reviewing code and pull requests [63]. Ponti et al. assessed 12 citizen science projects that made use of automation and found three main examples of contributor engagement with this technology; when algorithms produce errors, when algorithms are unable to complete their task, and when algorithms ask contributors for input [48]. These studies highlight the diversity and breadth of areas in which bots contribute to collaborative projects.

Geiger assessed the 'social role' of automation in the English-language Wikipedia [16]. Here, Geiger discusses the efforts towards automating aspects of Wikipedia as a process of distributed cognition. Given the staggering amount of edits made across Wikipedia, a combination of semi- and fully-automated tools are in use to add missing information to articles, initiate discussion between editors, and detect and counter vandalism, among other tasks. Hall et al.'s study on 'freedom versus standardisation' in the context of OSM [27] is highly relevant to our work. OSM is less strict in enforcing norms compared with the English Wikipedia [27, 40], but applications making use of OSM data still require structured data. Hall et al. interviewed 15 OSM contributors on their process of data contributions with a focus on this contrasting aspect. Their results show that the tools used for data contributions play a prominent role in shaping the norms that are applied, following Lessig's observations on the regulatory power of code [39]. Hall et al.'s participants furthermore expressed concern regarding the use of data import tools, as low-quality data can harm both the data integrity as well as the local mapping community.

Kiene et al. assessed the use of moderation bots across a total of 300 Discord communities and found that larger communities are more likely to incorporate bots [35]. On the other hand, they found no evidence that smaller moderation teams were more likely to adopt bots. Seering et al. studied the role of bots as social actors on the Twitch live-streaming platform [53]. Here, in addition to moderation, bots are used to foster user engagement, for promotion, and for mini-games. In analysing the message frequency of these bots, Seering et al. find that, while all viewers combined sent substantially more messages than the total number of bot messages (roughly 50 times more), bots significantly 'outperform' individual viewers in terms of messages per hour. The authors, therefore, conclude that "*bots have disproportionate influence on the tone of the chat if only by volume of text*" [53]. Gal et al. suggest that bots can be used not only to increase productivity but also to increase engagement in online collaboration projects, for example through motivational messages [13].

The vast uptake of bots and automation across numerous large-scale collaborative communities highlights the necessity of automated assistance in dealing with the extensive and constant stream of contributions. Despite the uptake of such automated tools, the literature also describes challenges in successfully integrating automation alongside manual community efforts.

2.4 Challenges of Automation

As one of the most prominent online collaborative communities, the use and challenges of automation on Wikipedia have received extensive attention in the literature. Müller-Birn et al. looked at the rising role of bots in 'algorithmic governance' across Wikipedia and pointed to two distinct characteristics of moderating bots [45]. First, automated edits are distinctly less visible, with editors being unaware of them and not all edits showing up on an article's history page. Second, the automated nature of algorithmic governance rules is enforced without discussion, whereas human editors may consider alternative aspects in their decision-making process. Geiger further highlights the notion of 'bespoke code' (i.e., code that supports automation on Wikipedia but which is hosted and maintained outside of the Wikipedia infrastructure) [15]. Due to this configuration, power over the code and its operation remains in the hands of a select few.

In a subsequent article, Geiger reflects on the decentralised governance structure of Wikipedia in relation to automation [16]. In this analysis, Geiger argues that the mere open-sourcing of bots or other automation software is not a cure-all for the issues raised by the introduction of algorithmic systems. Through two auto-ethnographic vignettes, the author highlights how the difference in needs and priorities between newcomers and moderators results in conflicts when bots are designed and maintained primarily to support Wikipedia's moderators. To break down the technological barriers that hinder the discussion of algorithmic systems on Wikipedia, Halfaker and Geiger present an algorithmic scoring system that aims to enable and support socio-technical conversations for a broader audience [25]. Following a five-year deployment period, Halfaker and Geiger show that their system is successful in decoupling the algorithmic system from its technological maintainers to increase the overall agency of the Wikipedia community.

Wessel et al. surveyed maintainers of open source software projects on their use of code review bots [64]. Their results highlight that bots were implemented to provide feedback to contributors, reduce maintenance burdens, and enforce code-testing rules. Their results also point to the potential downsides of these bots, which were found to add to the communication noise and result in dropouts among newcomers to the community due to their intimidating effect. In a subsequent study, Wessel et al. interviewed 21 developers on the same topic [65], offering a more in-depth understanding of these identified challenges. Ghorbani et al. assessed the impact of developer characteristics on bot preference and found that senior developers had a preference for more autonomous bots, whereas less experienced developers preferred bots with little autonomy [19].

Lastly, prior work has made initial attempts to understand how to design better automation for collaborative projects. Liu et al. focused on 'small scale' automation in open source communities and, based on an online survey involving 24 software developers, presented seven principles for designing bots [41]. The most widely agreed upon principles include 'be robust and stable', 'ensure transparency when bots take action', and 'keep bot responses simple and specific'. Liu et al.'s investigation exclusively relied on input from developers, due to its focus on GitHub. Given the aforementioned 'regulatory power of code' [39], as well as the broad impact of automation on collaborative communities [45, 48, 69], we extend our investigation to a more diverse audience containing both developers and non-developers.

These studies highlight the extensive socio-technical role of automation across multiple online collaborative projects and the numerous challenges this may introduce for human contributors. In this work, we first seek to understand how bots and automation are used in the context of OSM, and subsequently identify opportunities to better support collaboration between humans and bots.

3 OPENSTREETMAP: AN OVERVIEW

OSM is a project where participants collaboratively map the world. This can be local groups and individuals who survey their neighbourhood, but also users who refine the map based on aerial imagery even though they are located far away from the area they edit. The increased availability and affordability of GPS-enabled devices in the early 2000s has been one of the key technological enablers that allowed mapping enthusiasts to contribute to OSM [24]. Furthermore, tools, automation, and bots play roles in this process and support as well as supplant human efforts

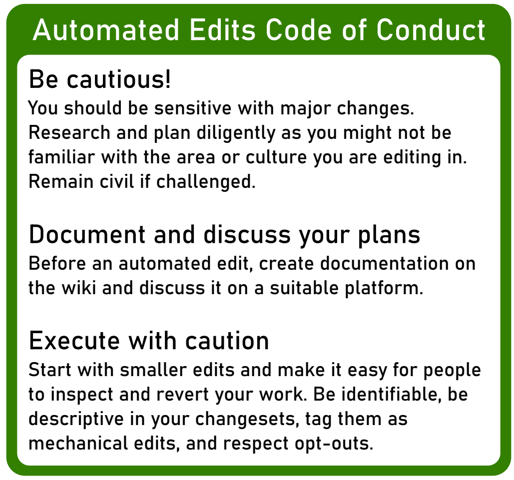

Fig. 2. OSM has a Code of Conduct for Automated Edits. We illustrate the main points of this code.

to improve the map. While the OSM tools allow remote mapping, there is substantial weight placed on local knowledge and community. This importance is also reflected in how the OSM community refers to the 'truth on the ground' as its ground truth[3].

OSM on the foundational level is a big database of nodes (e.g., a bus stop), ways (e.g., a street), and relations (e.g., a bus route). Ways that are closed denote an area (e.g., a lake). To each of those any number of *tags* (i.e., key-value pairs) can be added, such as for specifying a maximum speed for a road (`maxspeed=50`), or providing a name (`name=Tiergarten`). What tags should be used to encode information is only defined by convention. The OSM wiki, for example, points to several resources for finding tags to use[4], including several pages on the wiki itself. Which tags are accepted changes over time and tags are deprecated (i.e., not recommended for use anymore as there is no way to preclude tags) as new ones are proposed and introduced. As a result of this, tagging is a hotly debated topic and different local parts of OSM sometimes diverge, leading to globally inconsistent tagging practices.

3.1 Bots and Automation in OSM

OSM users generally do not interact with the database directly, but instead access it through tools or browse map tiles generated from it. There are several editors and APIs available for consuming and updating OSM data and thus a rich ecosystem of tooling has developed around it. This ecosystem also includes tools for automated editing, be it through scripts or bots. While OSM generally runs with little to no oversight or moderation, there is an expectation that such automated edits follow the 'Automated Edits Code of Conduct'[5] (main points shown in Figure 2). This code of conduct was established in 2008, indicating the long-term impact that bots and automation have had on OSM. The guidelines presented here highlight caution in performing automated edits, stressing the importance of discussing and documenting plans beforehand, aiming for consensus, and ensuring changes include a link to the documentation.

[3]See https://wiki.openstreetmap.org/wiki/Ground_truth.
[4]See https://wiki.openstreetmap.org/wiki/Tags#Finding_your_tag.
[5]See https://wiki.openstreetmap.org/wiki/Automated_Edits_code_of_conduct.

One particularly relevant body within the OSM community is the Data Working Group[6]. The Data Working Group is one of the OSM Foundation working groups (including, among others, the Communication Working Group and Engineering Working Group), and concerns itself with copyright, data policy, vandalism, imports, and bots. This working group consists of roughly 20 members, and has the authority to take action when conflicts arise or existing policies are not followed. As per the Data Working Group's description page, a large part of the work is in communicating these rules and established practices to newcomers to the OSM community.

Bots and automation can serve various functions and support different user roles in OSM, typically aimed at reducing the need for repetitive tasks. An example of this is the '`merylstreet semibot`'[7], which operates in the region of Nice (France). This bot takes external data on local waste recycling locations, converts it into a suitable format, and imports it into the OSM database. In contrast to the local edits provided by this bot, bots can also operate globally. changeAn example of this is '`b-jazz-bot`'.[8] This bot replaces any compatible website's URL in the OSM dataset from `HTTP` to `HTTPS`. Another recurring role of automation is importing external public-domain datasets. Such datasets, typically provided by governmental institutions, often contain geographic features that need to be carefully merged into the existing data format of OSM. An example of a large-scale data import is found in the Topologically Integrated Geographic Encoding and Referencing system (TIGER) dataset provided by the US Census Bureau.[9] The import of TIGER data into OSM became a notorious example of the challenges in data imports, with the initial import of this data being aborted due to data integrity problems. Finally, Facebook's 'Map with AI' project seeks to make mapping more efficient with an editor called Rapid.[10] Rapid combines satellite imagery with Artificial Intelligence (AI) to create map overlays of predicted features, such as roads, which human mappers can then edit or confirm. As seen from the examples above, bots and automation projects can target a variety of tasks and may range in scale from scripts written by one individual to large-scale community efforts.

Finally, common terminology in this space includes: 'scripts', 'bots', and 'automation'. 'Scripts' are normally executed manually and consequently run at an irregular schedule or are executed only once. Typical use cases for scripts are, therefore, actions that do not need repeating, such as fixing an incorrect data import. The term 'bots' is used to indicate operations that function in a more routine-based manner and often without direct oversight by the bot's creator. OSM bots crawl through the data of contributors to identify predefined aspects within the data and subsequently alter this data in accordance with the bot's instructions. This continuous operation by the bot ensures that little to no additional effort is required by the bot's maintainer to introduce and maintain certain rules. Lastly, the term 'automation' is typically used to describe all contributions and edits to OSM data that are not completely manual. This includes the aforementioned scripts and bots, but for example also the use of automated imports, in which large amounts of mapping data are imported from other sources.

4 DISCUSSIONS OF BOTS AND AUTOMATION

To build an understanding of how OSM users engage with bots and automation tools, we turned to a place where this is discussed: the OSM mailing lists[11]. OSM runs or previously ran 198 different mailing lists and provides archives for those. Messages go back to September 2004 and span almost

[6] See https://osmfoundation.org/wiki/Data_Working_Group.
[7] See https://wiki.openstreetmap.org/wiki/Mechanical_Edits/merylstreet_semibot.
[8] See https://wiki.openstreetmap.org/wiki/Automated_Edits/b-jazz-bot.
[9] See https://wiki.openstreetmap.org/wiki/TIGER.
[10] See https://wiki.openstreetmap.org/wiki/Rapid.
[11] Available at https://lists.openstreetmap.org/.

18 years up to late May 2022, when we started our analysis. With the exception of the first three years, the mailing lists saw a relatively consistent volume of about 30,000–50,000 messages per year. The aforementioned Code of Conduct for Automated Edits describes these mailing lists as the primary forum for proposing and discussing automated edits with the rest of the OSM community, making this a suitable data source for our investigation. Further, the discussions on the mailing lists allow us to understand how bots and automation are discussed and used in practice, as opposed to the desired practice that is described in the guidelines.

We downloaded the public mailing list archives (723,631 messages overall) and first processed it to remove personal information (e.g., sender information) and replace it with pseudonymous identifiers. We then used PostgreSQL’s full text search[12] to identify email threads pertaining to bots and automated edits. This was done by conducting two separate searches. The first search, using the term ‘`bot`’, returned 6323 messages. The second search, using the terms ‘`(automated | mechanical | semi-automated) <-> edit`’[13] returned 2303 messages. As the search results overlapped, this worked out to 8325 unique messages we then retained for further analysis.

We subsequently focused our investigation on mailing lists directed at English language communities, the general OSM discussion list, as well as specific mailing lists focused on OSM development, legal issues, tagging practice and rules, and automated imports, due to their relevance to our topic of investigation. Following these criteria, we included eight mailing lists in our investigation. These mailing lists are: *dev*, *talk*, *legal-talk*, *Tagging*, *Talk-au*, *Talk-GB*, *Talk-us*, and *Imports*. This is still a set of 1405 messages/threads so we decided to further limit this to messages that started (i.e., no `References` header is present in the email) a thread. With this constraint, our final set consisted of 446 messages/threads to look at more closely. Threads in this set were started between 2006–2022 with ~20% posted in the last five years. For each initial thread message on bots, we also include all follow-up messages in the analysis, whether they include the search terms or not. Overall, we ultimately had 4188 messages across all threads and thus included in our analysis. In our data collection and analysis we followed the ethics guidelines of our institution. In analysing these messages, we followed a reflexive thematic analysis approach, as per Braun et al. [4].

A reflexive thematic analysis approach emphasises the influencing role of the researcher in interpreting the data, and aims to “*examine the ‘factors’ that influence, underpin, or contextualize particular processes or phenomena*” [4]. We have made minor contributions to OSM, but are ourselves not active on these mailing lists nor do we have personal experiences with bots and automation on OSM. Through this inductive analysis of the threads, we sought to identify and group relevant codes. First, the authors separately read through a substantial subset of the threads as selected from all mailing lists to become familiar with the data. Subsequently, the authors engaged in an iterative process of reading and annotating the threads and discussing potential themes. Quotes and preliminary theme descriptions were shared and edited over multiple iterations in an online spreadsheet. With respect to the relevance of the messages to our study, we considered to what degree bots and automation are discussed. For example, a one-off remark in an otherwise unrelated thread was not considered relevant.

4.1 Identified Themes

We identified five themes in the messages on bots and automation we investigated: (1) on the tension between building consensus beforehand and fixing issues after bots ran, (2) on how bots interfere with the goal of community building, (3) on power differentials between people using

[12]See https://www.postgresql.org/docs/current/textsearch-intro.html.
[13]‘<->’ is a ‘followed by’ operator: https://www.postgresql.org/docs/current/textsearch-controls.html#TEXTSEARCH-PARSING-QUERIES

bots and people who do not, (4) on their use for repetitive and error-prone tasks, and (5) on the use of bots as a bridging mechanism to other communities. Next, we present the five themes in more detail. When quoting directly from the mailing list we provide the year in which the discussion took place in brackets.

4.1.1 Consensus Building vs. Post-hoc Fixing. The OSM guidelines for automated edits asks contributors to write up proposals, allow for discussion, and seek community approval before they run. However, in practice these guidelines are sometimes eschewed or the automated edits had unanticipated results. As an illustrative example, consider the following protest against a set of automatic changes that did not follow the code of conduct: "*Basically he admitted that he acted against OSM rules (there is no discussion, no documentation of changes), but he justifies it by the fact he is doing the right thing. Also, he claims that he is part of OSM since 2007 and if I don't like his changes I should find myself another mapping project (sic!).*" (2015). This comment exemplifies that many automated edits are run without community consultation. As another user put it in a different discussion: "*I objected to the fact you were making a series of mechanical edits without discussing it first. Your edits were in my view controversial, changing the shop and name tags as added by mappers on the ground. There is consensus that these sort of changes must always be discussed.*" (2014). Yet this discussion does not always take place and the burden to subsequently resolve issues introduced by automated edits is often put on the shoulders of other users. These comments furthermore highlight the inherit power imbalances that emerge due to automation, a theme we discuss in more detail in Section 4.1.3.

In contrast to the above examples, we also observed many instances where people did ask the community for feedback before a planned automated edit. As there is no prescribed way to reach consensus, there are different processes in place and any reached consensus is often small. For example, one user organised voting via their bot's wiki page and subsequently announced: "*The voting is closed now. All ten voters have voted 'Approve'. Thank you all for voting. I will proceed now with obtaining approval from the Data Working Group.*" (2013). The limited number of only ten votes shows that most of the OSM community does not get involved in these decisions. In this case, the user also tried to defer the final decision to OSM's Data Working Group, which led to some discussions around where the power to approve automated edits lies. As the same user as earlier then pointed out: "*Technically, the DWG [Data Working Group] only has the power to roll back mechanical edits, not to approve them in advance.*" (2013). This underlines the ad-hoc nature of the approval process and that, while consensus building is desired by the OSM community, the actual processes around that are lacking. As the code of conduct for automated edits states, "*OpenStreetMap is built on consensus, rather than a majority voting…*". Low participation in these discussion is, therefore, not necessarily a problem. However, it remains unclear how 'consensus' is to be interpreted.

Instead of consensus-building, some users also brought up the idea of limiting what bots can edit. For example, one jokingly noted on a bot changing how trees are tagged: "*Maybe we should set up some sort of equivalent of 'robots.txt' in which users can tell bots to stop molesting their data. ;-)*" (2010). Another thread discussed editing limitations in response to a comment pointing out that: "*This is the second time you have ruined hours of work that I have put into my map with bots. Please, please, stop using bots, and stay out of places you don't live in and have no knowledge of.*" (2012). Ideas then included ranking systems where edit access scales with experience and local moderators reviewing edits. However, this would not just restrict bots, but all users and, as others noted, bots are often run by experienced OSM contributors and ranking would not alleviate these issues. As one user wrote, "*Your solution, however, is directed at novice users. [username] isn't a novice. He thinks he knows better than other people.*" (2012).

Overall, we observed substantial tension around bots and script edits of OSM. When they go wrong, there is heated discussion and attempts at consensus building only reach a very limited audience at best and at worst are ignored. Presently, OSM signals the importance of consensus, but practically, a lack of procedures often incentivises users to run their bots and scripts as they see fit. As a member of OSM's Data Working Group pointed out: "*Most of these bots violate the 'automated edits' policies anyway and the only reason that they haven't been stopped and held to account is that Data Working Group haven't got the manpower. But we plan to be much stricter on automated edits and imports in the future.*" (2012).

4.1.2 Local Customs & Community Building. For many contributors, OSM is a project where they can engage with their local environment and community. In this light, edits from people far away from one's location or edits via bots and scripts are often seen as counter to that engagement. For example, in response to a data import query, a user responded: "*There is really no need to import this type of data in the UK where the mapping culture is to walk/cycle and just go and have a looksee.*" (2015). This is not only about culture, but also about data quality and local expertise. For example, when discussing the import of data from an external source, one contributor commented that, "*Leaving imports to local mappers is good. They are best able to assess the quality of the data for that area and care about quality of their local map data. It also leaves 'low hanging fruit' for them. Some areas without local mappers may take longer to 'finish'. That is okay.*" (2010). This is mirrored in another thread, where a user notes that: "*I've always seen OSM as proving that by local crowdsourcing, given enough mappers, we can produce more accurate data.*" (2011). But local engagement is not just about data quality and instead community-building itself comes up, such as when one contributor notes that, "*Unfortunately to most OSMers, community building seems hard (which it is), and writing bots or doing imports seems easy (which it's not).*" (2011).

But, while there is an ideal of local mapping, it conflicts with the realities of participation in OSM. As one user put it, "*I don't want to say the UK mapping community is dead, but it is not big enough to manage the volume of data we already have in OSM. Any tools that can help this situation ([examples]) would be welcome in my eyes.*" (2015). In a different thread, another user described in more detail how they would like contributors to focus on local engagement instead of bots:

> *"Why isn't the UK complete yet? Amazingly, in a worldwide community of 350,000 registered users (with thousands in the UK), we have:*
> - *just three people working consistently on a newbie-usable editor ([usernames])*
> - *someone in Germany working on a newbie-usable corrections platform ([username]'s MapDust)*
> - *no project-wide outreach operation*
> - *no UK outreach operation*
> - *no project-wide press operation*
> - *no UK press operation*
>
> *That is the sum total of the efforts to attract newcomers and thereby increase our coverage. The occasional attentions of four people. Out of 350,000.*
> *And your reaction to the fact that the UK isn't complete is 'hey, someone should spend a lot of time writing a bot'? Holy cow." (2011).*

One motivation behind the focus on local mappers and their expertise is the limitations of the automated 'one-size-fits-all' provided by bots and automated edits. We found a significant emphasis by OSM contributors to embrace local customs and insights rather than adhere to global standards. Here, the expertise of local mappers often took preference over ensuring a uniform mapping dataset. This sentiment of relying on local knowledge is reflected in practical aspects and broader beliefs around established community rules. As an example, when a contributor suggested the automated renaming of all locations of a store chain following a legal name change, another community member vividly expressed their concern: "*In many cases, the world doesn't change instantly at the behest of some guy in marketing or legal. Individual locations might retain their signage for various reasons and we map what's on the ground, not what's in the franchise agreement.*" (2016). Established practices can vary widely between geographical areas. These differences may result in conflicts during automated edits, as these edits can apply globally rather than be restricted to a specific area. On a proposal of the automated editing of the opening hours tag, a contributor comments on the lack of a global consensus regarding this data and therefore urges the bot to be limited geographically: "*I would suggest that, if at all, you only make these changes in Germany and not elsewhere, since much of the opening hours related discussion has really only seen German participation and I'm not sure if mappers elsewhere even agree with the way the Germans have decided to handle their opening hours tag.*" (2014). Local communities can differ in how they treat data in OSM, but also can have different approaches in how to negotiate these rules in the first place. For example, anecdotes in a thread on automated edit code of conduct paint the German OSM community as more rule-based: "*When I issued words of caution on the German list, some people came to me grinning and said 'well there you have it, that's what happens when you have a project without rules, and anyone making automated changes has the same right to do so as anyone else'.*" (2008). While at the same time describing the Dutch one differently: "*In NL [Netherlands] we would call this ultimate anarchy and unless one of our dictators steps in to stop anyone nothing happens. So if someone doesn't like automatic edits it should be able to be reverted easily...*" (2008).

The practice of tending to one's local surroundings on OSM is sometimes called 'gardening', a term earlier described by Seering et al. in relation to moderation tasks [54]. In line with this practice, users commonly express a preference for manual fixes: "*The point of this type of gardening is to fix errors like this and make a better map. Some people are happy to leave that there until a local mapper fixes it as it will ruin the local community if I fix. They will be threats or actual blocks/bans etc if any fixes this that has no local knowledge and does this in a mechanical way. Even using in conjunction with aerial imagery may not be ok.*" (2014). Some even point out that data should not be fixed automatically, because wrong data itself can be a piece of useful information: "*It is easy to run a script that removes all the Toys R Us-es, but that script would also destroy the valuable information that this general area of the map hasn't been updated since Toys R Us went bankrupt.*" (2018). Yet, this kind of gardening also takes time and large automatic data imports can be a burden for the community. As one contributor highlights: "*I think that even imports that are well executed *technically* are usually bad because they worsen the ratio of 'mapper hours available to maintain data' to 'amount of data requiring maintenance'. Imports should only be allowed if there is a realistic expectation that the presence of the imported data will lead to a growth in our community of about the number of people that would have been required to survey the imported data in the first place.*" (2012). These excerpts highlight the strong focus on community building, which is, at times, at odds with the use of automation.

4.1.3 Power Imbalances. The near limitless changes bots can make in a short time compared to manual contributors leads to an enormous power imbalance. Due to the speed and range with which automated edits can manifest, changes (including errors) can quickly spread through the project. This means that some users can bend the state of the map (e.g., how a feature is tagged) in a direction of their choosing. But it also pushes others into repair roles and having to play catch up to bot edits.

With manual editors having to resolve the errors introduced by automated edits, this often results in additional work. One contributor comments that, "*the urge to fix previous automated edits with new automated fixes is understandable, but it may lead to a more casual approach to imports and* *automated edits, because we basically say with each fix that ill-informed automated map edits can always be fixed with more automated edits later.*" (2019). While often well-intended by the creators of bots, this feedback loop results in an increasingly polluted database in which it is progressively more challenging to revert or resolve these errors. One contributor contrasts this with how bots are handled on Wikipedia, by noting: *"Bots were successful in Wikipedia because all users felt empowered. Users could very easily see what the bot edited, fix or undo bot edits, and easily communicate with the bot authors. OSM does not have as good of tools to compare and undo. Hence, some users in OSM may feel powerless [. . .]"* (2017). Some also perceive the reliance on data imports and automated edits to resolve data issues as a state of *laissez-faire*, where they are in a position with less leverage.

The discussions at times reveal underlying stigmas about the motivation and interests of those in favour and control of bots and those pursuing manual contributions. At times, the latter expressed a sense of threat of being overrun by automated edits: "*First, I am among the majority of OSM members who do not program or write code. Yet, we also contribute, heavily. I don't think writing code makes one some kind of special contributor.*" (2012). In the same discussion, this contributor expressed discontent with how a decision was made: "*It may have been open and transparent if you know how to write code, but I saw little nontechnical discussion.*" (2012). This exemplifies the challenges faced in discussing automated edits, in which technical details can act as a barrier to engagement with a broad audience. Most users are reliant on the editor tools available to them, which is a power imbalance on its own, as one user pointed out: "*Meanwhile, editor writers and bot programmers gain all the power—it is, in effect, them who decide what gets tagged how [. . .].*" (2011).

We saw several other examples of users explicitly pointing out the power difference between those with and those without bots. For example, one user specifically calls out bot writers: "*The use of bots puts too much power in the hands of those who write them, and this must be balanced by a requirement to involve the non-bot-writing part of the community before launch.*" (2020). In another thread (subject line, *"think before you bot"*) a user mirrored that sentiment, noting: "*This is just a general plea to those using bots. Please use your immense powers with extreme caution. There seems to me to have been an increase in bot edits lately, and some of them are becoming very bold.*" (2010). While these comments point to the same sentiment, they were raised ten years apart. This, and other discussions on the OSM mailing lists, indicate that although the issues surrounding the power imbalance introduced by automation were already well-known, little progress has been made to alleviate these issues.

Overall, bots and scripts give some members of the OSM community a larger amount of influence on the state of the map than others. As not everyone possesses the necessary technical skills, this power is not available to all and users are cognisant of the resulting power imbalances. With many asking for more involvement of a larger share of the community before bots and scripts are run, this also relates back to the tensions around consensus building.

4.1.4 Alleviating Repetitive and Error-prone Tasks. Despite the myriad of challenges faced in the use of bots and automated edits, their continued use is based on a need expressed by at least part of the community. The importing of rich mapping datasets (e.g., as provided by governmental institutions) as well as the maintenance of the extensive database can be supported by automated processes. The work of bots not only serves to reduce menial tasks, but also ensures consistent outcomes free from human errors. As one comment in response to a critical perspective on automated edits reads: "*It would be easy to say 'Manually fix the data', but I can tell you from experience that going around and manually fixing 'Rd' to Road is not fun, and can, with the TIGER imports, be done safely [. . .] I've spent many hours manually examining two polygons of the same geometry (some which share the same nodes, others which do not) only to remove one. Having users do these kind of operations adds nothing but 'busywork' and is error prone.*" (2012).

In response to concerns around local engagement (see Section 4.1.2), it is often pointed out that automated imports and edits could, in fact, boost participation. For example, one user notes: "*Will this discourage mapping? I don't believe so—there will still be loads of landuse and paths to add, it will just free people up to do that work rather than repetitive jobs that a computer can do. By getting the UK mapping up to a good basic standard then more people will start using it and will thereby be encouraged to add more detail where they need it.*" (2011). This is mirrored in another thread, where a user points to previous experience from the Netherlands: "*I still think we are using a lot of expert time to do very mundane work less well than a computer would manage. Anyone who says that bulk imports will damage the community should take a look at the Netherlands where they did a bulk road import some years ago and have a hugely strong community now. [. . .] The bot will still make it clear that a manual survey has not been completed of the area and invite people to take a look. It will free up human effort to do work that can't be done by a computer.*" (2011).

To many OSM contributors the benefits of automation are tangible and attractive, even though at a community level the drawbacks of automation are well understood. The general discussions of automated edits, imports, and bots frequently highlight the complex relationship between automation (often promising speed and scale) and manual work (focusing on human intelligence and understanding). As exemplified in the following statement, the use of automated edits is often perceived as unavoidable despite the downsides it might introduce: "*I think imports and bots are inevitable, so the more documented we make the process, the less we encourage people to go wild and write their own. At the same time, we want to discourage bots and imports in general.*" (2010). The creation of protocols and documentation for conducting automated edits, however, is impeded by disagreement among community members about the added value of automation and the potential risks it brings to the community. Despite this disagreement, fixing mundane errors like typos, importing data from elsewhere, or deprecating tags are all tasks that are widely perceived as being time-consuming, error prone, and unengaging.

4.1.5 Bridging Platforms. The OSM project does not operate in a vacuum, and bots play a prominent role in enabling a connection with other projects. This includes OSM data being used in other applications and data coming into OSM from other platforms.

One example where bots bridge communities is with wheelmap.org. This site offers a dedicated map where users can look up accessibility information for businesses, transit, or public places. Users can also directly correct information on that map, which is fed back into OSM using a bot. That itself is not problematic, but some users had issues with the arbitrary changesets introduced by this bridging bot. As it bundles edits by time instead of locale, this clashes with OSM users' expectations for locally constrained edits.

Bridging data to other community projects is similarly not without challenges. We encountered multiple requests from contributors to link to Wikidata entries in OSM entities. Wikidata is a storage repository of structured data, part of Wikimedia, and an example of a data source with relevant but distinctly different data from OSM. This data platform could provide information on, for example, a city's size, a building's materials, or photos of a point of interest. The discussions around this potential integration of Wikidata data into OSM show a repeating pattern of hopeful expectation of automating this process, followed by discouragement when faced with the anticipated technological challenges. For example, one script uncovered erroneous data when linking OSM and Wikipedia data, demonstrating a benefit of such an approach: *"This tool is an unexpected result of creating a detector of interesting places based on OSM Data and Wikipedia. It turned out to require a filter to avoid invalid links."* (2021). In what to connect to, one contributor also brought up the notion of 'project closeness': *"So there will be many things we map that will have Wikidata items, but not Wikipedia articles. And some where our information is more specific that what WP has. Wikidata*

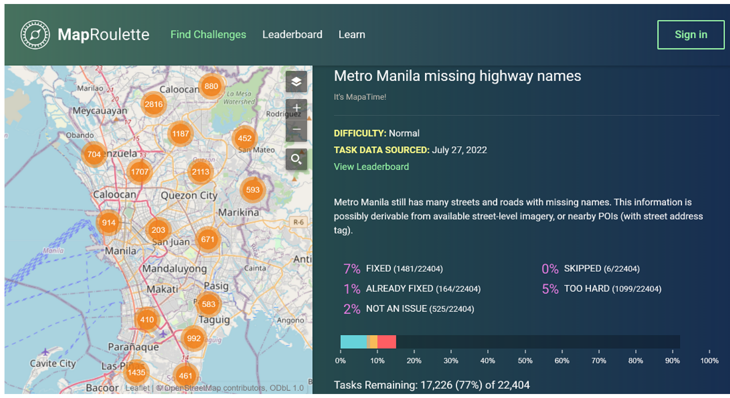

Fig. 3. MapRoulette is a site where human users can solve small OSM tasks, primarily for cleaning up after imports and fixing errors identified through scripts, but not yet fixable through automation. As such, it is a form of collaboration between humans and automated scripts where both sides contribute their strengths.

is actually an opendata project that stands closer to OSM than WP, or it certainly can be." (2017). Another contributor comments on the limitations faced by bots: "*I don't think this should ever be done without a human check, because there are often several related objects with similar names near each other. [...] In my opinion, the risks of doing this automatically are just too high.*" (2014). This example highlights the limits of understanding associated with automated edits and the need to keep humans in the loop.

Attempting to overcome some of the limitations faced by automated edits and to rely on human intelligence, various gamified crowdsourcing interfaces have been developed. Tasks on these platforms can often be completed without being an expert on OSM, providing a low bar to entry for interested newcomers. A widely used platform is MapRoulette[14] (see Figure 3). An example of a recent task on this platform asks contributors to find the website of museums in the USA that currently do not have a website listed in OSM. These crowdsourced and often gamified initiatives sometimes serve as an alternative to automated edits due to their ability to break larger tasks into distributed small-scale tasks. For example, a discussion on road crossings describes the lack of a metadata indicator as to whether a given crossing also serves as a designated pedestrian crossing (*i.e.*, zebra crossing (UK), marked crosswalk (US)). Rather than relying on automated edits to assign the correct tag, a contributor suggests the use of a crowdsourced approach: "*Perhaps Maproulette would be a better option? Zebra markings would often be visible on aerial imagery, and a comparison of newer vs older imagery might allow people to identify recent changes.*" (2019).

Finally, OSM users also draw on their experience with bots on platforms like Wikipedia when discussing automation on OSM: "*Personally, I have an issue with Wikipedia which, at least in some less-frequently visited corners of the project, often looks more like a bot playground than a collaborative project by humans. This negative impression (page last edited by a human a year ago, and after that, 10 edits by bots) also informs my skepticism towards mechanical edits in OSM.*" (2019). Another user similarly applied that reasoning to clean up edits by bots, writing: *"I don't want us to go down the Wikipedia route where we have an army of bots running to 'clean up' contributions. If there's a consensus that a tag is unnecessary then put it in the major editors."* (2019).

[14]See https://maproulette.org/.

4.2 Summary

The five themes we identified shed some light on the conflicts within the OSM community when it comes to automation. As highlighted in these themes, the challenges and benefits of automation touch upon many different aspects of OSM. Consequently, the content of our themes occasionally overlaps as, for example, seen in the friction between the ideal of building consensus (Section 4.1.1) in a reality of power imbalances between community members (Section 4.1.3). Similarly, automation of repetitive tasks also requires consensus on how this should be done. Many contributors desire consensus, local community and engagement, as well as equality between contributors. At the same time, there is a need for help through bots and scripts as there are large amounts of data to import, update, and maintain. These two aspects are frequently at odds with each other.

5 SURVEY ON AUTOMATED EDITS

Building on our analysis of OSM mailing lists, we reached out to the OSM community to further investigate how they engage with bots and scripts. In doing so, we aimed to obtain a deeper understanding of the perceptions of OSM members towards bots and automation as used by either themselves or others, as well as the current and future infrastructure that supports this interaction. In particular, we were interested in their approaches to tackling the challenges and tensions we described earlier. Finally, this survey allowed us to understand contemporary challenges, thereby ensuring that the challenges identified through the mailing list archives are still present.

We created a survey to collect responses on (1) participants' experiences with other people's bots and scripts, and (2) participants' experiences with running their own bots and scripts. We also asked participants for demographic information as well as information on their overall involvement in OSM, with both being optional. The full survey can be found in Appendix A. For remuneration, participants could enter a raffle for a $25 voucher. We posted a call to our survey to the *dev*, *talk*, *Talk-au*, *Talk-GB*, and *Talk-us* mailing lists. We ensured that our data collection was in line with the ethics guidelines of our institution. Similar to our analysis of the mailing lists (Section 4), we used a reflexive thematic analysis approach to identify themes in the survey responses.

Our call resulted in a total of 45 responses. The majority of our respondents were from the USA (10), the UK (9), and Germany (6). Their average age was 47 (SD = 13.9). In terms of gender distribution, 29 respondents were male, 3 were female, with the remaining 15 respondents choosing not to provide this information. This gender ratio is in line with a previous study by Budhathoki and Haythornthwaite [5], but with a higher share of male respondents than more recent work by Gardner et al. [14]. However, the latter notes this might be "possibly due to the focus of the survey on contributor demographics", where our focus on bots might have attracted more males.

When asked about bots and automated edits by others or their own, 23 respondents indicated at least some prior encounters or experience. The remaining results are based on the data provided by that subset of respondents.

5.1 Results

We identified three main themes along our main lines of questioning, each concerning a different phase of running and encountering bots. First, participants reported on engagement with the OSM community prior to conducting automated edits and what work they conduct in preparation. Second, participants reported on processes for handling errors from automated edits and how these can escalate. Third, participants described ways to bridge the gap between automated edits and community discourse, in particular with respect to changes to the digital infrastructure of OSM. Overall, these comments provide an account of how contributors try to (1) prevent issues, (2) resolve issues, and (3) envision changes to reduce the number of potential issues in the future.

5.1.1 Preparing for Automated Edits. When asked how our respondents engage with the community prior to making an automated edit many reflected on the established policy on automated edits. This highlights that our respondents were generally well-aware of the protocols. Example comments include: "*talk, talk, talk :) and wait enough between the talk and the automated edit*" (P23) and "*I strongly believe in communication early on*" (P21).

Respondents further stressed the role of locality in preparing for edits. By engaging with the local community, edits are more likely to align with the mapping standards of that area. "*I think that if mappers are using bots or automated edits, they should post an email to the email list for the country in which the edits appear (for example, if the bot or automated edits were done to U.S. data, they should email the OSM-US email list) so that their work can be checked by others and 'validated' or not*" (P17). As an added benefit, such a split by country or area reduces the overall size of the changeset—making it easier to revert any erroneous changes. Changes at a global scale, such as shown in Figure 1, are clearly frowned upon: "*The most important point is to not change the whole world at once, but to split the automated edit by country. Then sending a message to the relevant country mailing list or forum would be necessary before starting the changes, at least to make sure that the changes are acceptable*" (P13).

Despite the widespread understanding among our respondents of the rules of running automated edits on OSM, we also found several examples in which the established procedures did not function as intended. In presenting their proposed automated edits to the community, bot creators often ran into tensions by those opposed to the use of automated edits. For example, one respondent describes their annoyance with a repeating pattern they encountered when sharing their plans with the community: "*It's a little annoying in the initial discussion of this sort of project to have to defend the very idea of mechanical edits. The knee-jerk reaction that any mechanical edit damages the community and that all time spent on bot development would be better spent on recruitment does not fit the problems of mapping in extremely sparsely populated areas*" (P06). Such experiences might ultimately result in bot creators being less likely to share their planned edits with the community. A different participant commented on their own change of behaviour in terms of engaging with the community, highlighting how their initial stance of communicating frequently has changed over time: "*I used to do it a lot more via them mailing lists, now I don't really, unless I'm unsure on something*" (P16).

5.1.2 Escalation of Error. When asked how our participants engaged when encountering errors introduced by the automated edits of others, a clear pattern of escalation emerged. As a first step, respondents often commented on the changeset itself—with each changeset featuring a simple discussion board (see the left-hand side of Figure 1). "*First is to raise a changeset comment, followed by the email list talk-au for confirmation and for awareness. Once it has escalated to the DWG [Data Working Group]*" (P21). If they are unable to get in touch with the bot creator, our respondents typically turn to other channels. This includes the mailing lists or specific working groups: "*I usually comment on the changeset in which the edits were made. Sometimes I message the other mapper instead. If I don't get any response within a few weeks and the edits were here in the U.S., then I would probably post an email to the OSM-US email list*" (P17). While uncommon, people have developed their own bots to undo the incorrect behaviour of other bots: "*In extreme cases, I've developed fixup bots (largely when enough edits have been overlaid atop the automated edit that reversion without damage isn't an option)*" (P06). Interestingly, local ownership also played a large role in how our respondents dealt with errors. Errors encountered in areas in which the respondent was actively involved were more likely to be resolved directly rather than escalated for discussion. "*Correct clear errors in 'my territory'*" (P30).

The discussion of errors encountered in the automated edits of others clearly highlighted the resistance to automated edits present among a part of the OSM community. One respondent stated, to express their dissatisfaction with the automated process directly to the editor: "*Providing I am acting in accordance with Wiki advice, I freely change tags that have been automatically added, without consultation with the originator. I often leave a changeset comment after the event, being critical of the automated process*" (P31). Others were more outspoken on the damage caused by automated edits and the costs of automation to the community. For example, one respondent suggests financial retribution in the case of errors made as a suitable strategy to reduce the number of errors introduced through automated edits: "*Fix the problem and have the person/organization that has initiated the edit pay for the time spent on that. If those making automated edits would need to cover the full macroeconomic costs of their edits the situation would become self regulating*" (P35). Finally, one of the respondents suggests that the practice of automated edits should be retired and replaced by bots that merely 'signal' that there is a possible error in the data. While not a widely shared perspective among our participant sample, it is exemplary of the challenges experienced in collaboration with automation. "*Bots should only signal issues, and edit nothing. If a bot edits things, it should be reported to the DWG [Data Working Group], edits should be reverted by the DWG and the creator should be banned*" (P30). Other respondents were more understanding of the errors introduced through automation, with errors being commonplace among (new) OSM members: "*Start small, and do more automated edits. There (sic) not magic, everyone's first edit to OSM is probably wrong in some way, so are there (sic) automated edits*" (P16).

5.1.3 Future Automation Infrastructures. As a final aspect of our investigation, we asked participants to share their visions on possible digital infrastructures to support the interaction with automated edits. Here, we hoped to better understand how OSM members themselves see the topic of bots and automated edits evolve as part of the community.

Enhancing the way in which contributors can communicate with bot creators was a common request. While some respondents simply proposed the sharing of email contact details: "*A direct way of contact would be nice, so not just the osm.org messages but rather a mandatory email address to a real person maintaining the bot/automated edits*" (P32), others proposed the creation of a public repository of bots. Here, respondents envisioned that such an archive would allow them to engage in discussion with the bot owner(s): "*Bots would be registered in a centralized system that has a publicly visible discussion you can engage with*" (P42). Furthermore, it provides a mechanism for them to evaluate the performance of specific bots: "*It would be nice to have a rating for that particular bot or user to see how many of their edits people have issues with*" (P39).

A lack of appropriate communication tools was also highlighted as a critical area in the initial discussion on automated edits. The current process, in which community members propose their automated edits to a mailing list was considered by many as rudimentary. While established guidelines, such as the building of consensus around proposed changes, were seen as valuable to hold on to, current techniques did not satisfactorily support these guidelines. Respondents particularly desired the ability to have insights into automated edits prior to their deployment. Different implementations of this concept were presented, including the use of a test server: "*Do the edits on a test server and let the community review these changes. If the community approves them (e.g. by a certain voting period), the edits will be applied to the production database*" (P32). Another respondent similarly suggests: "*Testing in a sandbox that held up to date copy of OSM data*" (P41). This functionality was also suggested by bot creators, as the current tooling makes the validation of bot actions a labour-intensive process: "*It's tedious to review every single change my automated edit is going to make, but that's what I do*" (P28). Furthermore, rather than bot creators being the only ones to automate edits, one of our respondents suggested the ability for all OSM contributors to highlight aspects that require automated edits, thereby democratising the process of automation. "*Ideally a user should be able to submit that a problem is automatable (deprecated tag, incorrect tag, ...). These reports would be collected and visible with the number of occurrences worldwide or by country*" (P23).

Several respondents raised the need for additional moderation of automated edits. These respondents were typically critical of the policies currently in place, as these are easy to circumvent and therefore do very little to prevent damage to the community. One respondent commented: "*Refrain from automated edits. In >90 percent of cases of automated edits those making them have no idea of the damage they are doing to the OSM community this way or they know, but don't care. Both disqualify them from making those edits. That also means any nuanced policy would have rather limited effect because those who would need to consider it are either unable or unwilling to properly do that*" (P35). To overcome the limitations of the current policies and guidelines, respondents pointed to the creation of automated rules for identifying and correcting undesired bot behaviour. This includes, for example, bots or automated edits deployed without consultation: "*Another approach would be to automatically revert any bot/automated edit that was not first discussed with the community*" (P04). Keeping a more detailed record of automated activities also plays a central role in communicating responsibilities. One participant stresses the need for "*better practices for documenting the mechanical steps made to do an automated edit, so that the reasoning behind them, and possible flaws in them, is more transparent*" (P28). These suggestions go beyond the current practice of changesets, which are identical for automated and manual edits.

Finally, the extensive role that local knowledge plays in OSM mapping practice was also highlighted in participants' reflections on future automation interactions. Here, participants sought to be more aware of any edits that took place in the areas they are familiar with: "*Ideally software would provide me with edits done in areas I'm familiar with so the quality of the edit can be determined*" (P04). Participants generally expressed a feeling of responsibility of 'their area(s)', and staying up to date with any edits happening in their area was therefore considered as valuable by many: "*I'd like the possibility of better alerting to areas that I actively maintain. Some place that I could check for 'recently modified items that I'd previously edited' would be helpful, I think*" (P06).

6 DISCUSSION

Our results provide an understanding of the ways in which bots and automation interact with the work of human OSM contributors. We next reflect on how these findings relate to the larger role of automation in online collaborative projects and outline potential directions for future work.

6.1 Perceived Benefits and Drawbacks of Automation

Bots and automation play an extensive role in large online collaborative projects, taking up a substantial amount of edits and contributions across projects such as Wikipedia [58], Twitch [53], and GitHub [20]. Prior work has highlighted how such work can reduce the burden of maintenance [64], assist in moderation [53], and offer feedback to contributors [69]. Our results indicate that the sheer volume of OSM data that needs to be maintained results in many community members perceiving automation on OSM as inevitable. While this viewpoint is occasionally contested, most discussions related to bots and automation focus on specific implementation and deployment aspects (e.g., geographical boundaries, labelling preferences) rather than the overall usage of automation. The inevitability of automation has previously been discussed in HCI in the context of human-AI collaboration at the level of individuals. For example, Wang et al. described that data scientists ascribed various roles to automation: that of collaborator, teacher, and autonomous data scientist [62]. Our study highlights that the perceived inevitability of automation also manifests at the community level. Currently discussed implementations of automation focus primarily on the role of autonomous OSM contributors, with relatively few occurrences of automation in a collaborative role. We did not identify automation taking on a ‘teacher’ role in the data analysed. These gaps highlight opportunities for future work to explore more diverse roles for automation at the level of communities rather than individuals.

A perceived benefit of automation that has not been extensively highlighted in prior work is the enabling role of automation in connecting OSM data with other crowdsourcing platforms (and *vice versa*). By creating links between OSM objects and other data repositories (e.g., Wikidata), complementary information outside of OSM can be accessed, automatically updated, and applied in innovative applications. A recent example of this is the linking of streets in OSM with persons in Wikidata after which the streets are named [22]. When discussing the possibilities of connecting data sources across projects, discussions often focused on the perceived closeness to the project in terms of community and values rather than technological aspects. While prior work has highlighted how community identification can benefit collaboration within a community [46], these findings suggest that overlap in principles between communities may positively affect the exchange of information.

Despite the perceived benefits of automation, automated edits also introduce a variety of challenges. Even factually correct data imports on previously unmapped areas may not be perceived as beneficial by all community members. In contrast to the work by Wessel et al., which points to the creation of additional work for GitHub maintainers due to bots [64], the challenge is that there may not be any local contributors to expand on automated imports (typically limited to road networks or other high-level infrastructure). Several respondents hypothesised that it is easier to attract new contributors if no data had been mapped as opposed to contributing to an area in which the high-level infrastructure was already present. In previous research, the opposite effect has been observed where an automated import sparked contributions around the time of import [67]. Similar criticism has been raised in the Wikipedia community with respect to *Lsjbot*[15]—found to be the most productive bot on Wikipedia [23]. While Lsjbot created a vast number of articles, resulting in the relatively small Swedish Wikipedia community being one of the largest Wikipedia editions, the articles produced were only initial stubs that required further expansion by human editors [31]. As such, the contributions by automated edits in uncovered aspects of a collaborative project may result in ‘collaborative deserts’, in which it is challenging to attract new contributors to expand on initial drafts.

6.2 Impact of Automation on Collaborative Communities

Our results highlight diverging opinions concerning the use of automation in collaborative communities. Since automated edits can operate continuously and virtually without restriction, their effects can be widespread. This especially holds in OSM, with only limited oversight and rules in place [27, 40]. Therefore, the perspectives of those without the technical skills or interest in deploying automated edits can easily be set aside. Consequently, our findings indicate that little has changed since 2011, when Lin et al. concluded that “*technical skills, types of knowledge, [...] are interlinked with the roles one holds [in OSM]*” [40].

As online collaborative projects grow, divergent standards are likely to emerge between different subgroups. This process has previously been labelled as ‘communities of practice’ (CoP) [38], and originates from the field of Education. Lave and Wenger describe that learning is situated, builds on shared practices within a group, and that knowledge within the group is developed through interaction [38]. Within HCI, this concept has been used to study and reflect on differences between various CoP. For example, Hara et al. conducted a cross-cultural analysis of different Wikipedia

[15] See https://en.wikipedia.org/wiki/Lsjbot.

language communities and found substantial differences in how these various CoP operate [28]. Their results indicate a higher share of courteous messages on the talk pages of Eastern Wikipedia communities than Western Wikipedia communities, which they attribute to differences in power distance between these cultures.

In our own results, we observed regional differences in the collaboration between OSM contributors. Of particular relevance is the dissimilarity in both the guidelines and daily practice of the tagging of information—with many countries following different standards. Prior work has stressed the limitations introduced by human editors unfamiliar with a particular area, pointing to limited knowledge [59], and unequal distribution of contributions due to a focus on well-known locations [44, 59].

Our results show that automated edits similarly result in issues when making edits across regions, a problem further exacerbated by the fact that automated edits can more easily extend across geographical borders. In contrast with Hara et al., who describe differences across multiple Wikipedia CoP along a cultural dimension (East vs West) [28], we highlight that geographically and culturally similar communities equally experience clashes due to automation (see e.g. the mailing list discussion on local custom in Germany and the Netherlands in Section 4.1.2).

6.2.1 Contrasting OSM and Wikipedia. Wikipedia is an established large-scale community in which bots and automation play an extensive role. While not without its challenges [16, 18], we find that the use of automation is less contested on Wikipedia than it is on OSM. Rather than recommending OSM and other online crowdsourcing communities adopt Wikipedia's approach to bots and automation, we seek to understand the similarities and differences between these communities in relation to automation. The use of bots and automation can impact collaborative projects differently due to organisational, technological, and socio-technical differences.

On a community level, both OSM and Wikipedia run as decentralised projects, in which community members have a large degree of autonomy and are self-organised. In the documentation and discussions regarding automation, OSM follows the stated goal of community-wide consensus. In practice, however, there are varying levels of consensus with local rules and decisions. Both the English Wikipedia and OSM have official administrative roles to approve, deny, and block bots based on user submissions and complaints. These are, respectively, the Bot Approvals Group[16], and the Data Working Group, as discussed in Section 3. Through our analysis, we found only a minimal level of oversight in OSM's usage of automation. This extends the findings of prior work on oversight of human edit activity [27, 40], which found that OSM is less strict in enforcing norms compared with the English Wikipedia. Consequently, those with the technical knowledge and interest in developing their own bots have extensive influence on edits made in OSM—resulting in the identified power imbalances (see Section 4.1.3). Future work in this area could take inspiration from Halfaker and Geiger's work on 'ORES' [25], an algorithmic scoring service specifically designed to allow for input and discussion from a broader set of community members.

On a technological level, contributions made to OSM and Wikipedia differ significantly in how they are stored and presented. Unlike Wikipedia, where it is relatively easy to revert edits and obtain an understanding of an article's edit history, technical constraints in OSM make it more difficult to undo or take control over bot edits. As the data in OSM is highly interconnected, changes made to one element can easily affect other elements of the map. For example, a path can be part of many relations, such as bus routes, hiking paths, or boundaries. In case an element has been subsequently edited by other bots or human editors, it is nearly impossible to revert incorrect changes without introducing new problems to the connected elements. In addition, while content on Wikipedia can be verified and validated from virtually anywhere, the 'truth on the ground'

[16]See https://en.wikipedia.org/wiki/Wikipedia:Bot_Approvals_Group.

philosophy applied throughout OSM makes it challenging to moderate both human and automated contributions.

The organisation of Wikipedia communities by language (e.g., English Wikipedia, French Wikipedia) shows similarity to the primarily country-based organisation of OSM (e.g., UK, France). On both Wikipedia and OSM, communities have a large degree of autonomy in determining their own community guidelines. The mostly siloed nature of Wikipedia communities also applies to automation, with most bots operating within the limitations of a specific community. While OSM's Automated Edits Code of Conduct suggests discussing any automation plans with the local community, bots can freely operate across country borders despite differences in local mapping customs (see Section 4.1.2). Due to the nature of mapping data, the country-based OSM communities are inherently more intertwined than the various language editions of Wikipedia. For example, navigation applications require a certain consistency in data formats when planning for cross-country travel. This issue of overlapping and conflicting concerns across sub-communities of collaborative projects is not exclusive to OSM and can arise in a variety of projects. For example, prior work by Smith et al. described how bots impact the sense of community on Reddit, such as through the enforcement of norms and through their impact on user perception and behaviour [55]. Our results show that automation can increase conflict between sub-communities and, therefore, require a greater degree of interaction between these otherwise autonomously operating communities.

6.2.2 Democratising Bots and Automation. Given the extensive impact of bots and automation on OSM practice and its impact on the distribution of power, we next reflect on our participants' suggestions to democratise and incorporate automation in collaborative communities. Participants' responses indicate that the currently used communication tools misalign with the needs and requirements brought on by automation. Mailing lists and message boards do not provide the necessary functionality to assess the quality of automated edits. Examples of desired functionality include support for (1) assessing which areas or elements will be impacted by a proposed automated edit, and (2) directly commenting on or annotating such proposed edits. Therefore, novel infrastructure and tools are required to allow more meaningful communication on the content of automated edits. Rather than restricting or limiting the automated edits that can be made, such functionality would provide bot contributors with the ability to be 'better citizens' in the OSM community. These pointers build on the previously identified need for socio-technical tools as presented by Hall et al. [27], who suggested developing data import tools to verify the correctness of imported data. While this suggestion by Hall et al. focused primarily on contributions by organisations 'external' to the OSM community, our results highlight the need for additional socio-technical tools for collaboration within the OSM community. As discussed by Ponti et al. [48], it is presently unclear whether existing and future bots and AI tools will lead to more democratisation and participation. Previous experiences with AI collaboration in the Zooniverse project were promising, but also pointed to several open issues, such as shifting demands in volunteer skills. Such concerns have also been echoed by Lotfian et al. [42], particularly with respect to the engagement, data quality, and ethics of citizen science projects. They also note that chatbots might be a suitable tool for guiding and engaging participants in citizen science projects.

Another detrimental factor in automation is the limited degree to which the authors of bots can be held accountable for the actions of their bots. This was particularly frustrating for those having to manually undo incorrect changes. To heighten the degree of accountability, as well as ensure the visibility of automated edits [45], respondents suggested the creation of a bot repository. Such a repository could enable community members to discuss and moderate specific bots before and during their use. While it is unlikely that such repositories can overcome the challenging tasks of finding consensus in a large community, prior efforts from the CSCW community may help to inform the design of such discussion tools [66, 70].

6.2.3 Comparing Automation with Large-Scale Manual Edits. Edits from bots differ from edits by regular users and some tensions and issues arise from that. However, bots are not the only case where edit behaviour differs. Other examples are corporate edits, humanitarian mapping, and mapping challenges. In each of these cases, other editing incentives and dynamics are at play than in regular map editing.

As described by Anderson et al., many edits to OSM are made by corporations [1]. For example, the 'Apple Data Team' is comprised of hundreds of people and has contributed millions of edits. Over time, the amount of corporate edits has grown—in total as well as relative terms [51]. One concern raised with corporate edits is that their data could be "*taking away the benefits of crowd-wisdom and local knowledge for which [OSM] is recognized*" [1]—a worry also mirrored with respect to bot edits. Furthermore, commercial actors on OSM are perceived as exploitative by some [52], which potentially translates to bot use as well, where access and use are similarly unevenly distributed.

In addition to regular mapping activity, sometimes out-of-the-ordinary events occur that change the mapping dynamics. One example is humanitarian crises, such as when mapping closed roads and destroyed buildings following an earthquake [30, 57]. But such 'large-scale data production events' can also be planned big imports or local mapping parties [21]. One aspect mentioned with respect to such larger activity clusters, but also the corporate entities mentioned above, is that these can appear as 'black boxes', where bigger actors (e.g., international organisations or companies) can "*appear as a huge single homogenous actor*" and thus explain and exacerbate existing asymmetries [3, 21]. These asymmetries are also a feature of bot use on OSM and have been brought up in our analysis.

As discussed in Section 4.1.5, there are several initiatives for bridging platforms and tying together data from OSM with data from other sources. Whereas the aforementioned mapping events are more focused, projects like MapRoulette are longer-running activities, but both result in large-scale edits of the map. Instead of a dedicated activity, map updates can also derive from people's movement traces [60]. In either case, map updates are not made through OSM edits, but through engagement elsewhere and are similar in nature to bot edits. This again connects to the above-mentioned concerns around mapper expertise and community. As these examples highlight, collaboration challenges instigated by external events or imbalances of power are not exclusive to bots and automation.

6.3 Making Human-Bot Collaboration Work

While our results highlight that not all community members are in favour of the use of bots and automation, we found that many consider the use of automation inevitable in managing and extending the vast amount of OSM-related data. Similar sentiments have been raised in other collaborative communities [8, 64].

While the use of bots on Wikipedia has been studied extensively (see Section 6.2.1), our results highlight unique aspects towards collaborating with automation. Given the complex socio-technical nature of online collaborative communities, no simple fix to address the challenges that emerge around human-bot collaboration exists. To inspire future research and development towards automation in collaborative communities, we outline the primary identified challenges and proposed directions for overcoming these challenges in Table 1.

In addition to the bots and automation investigated in this paper, recent work has focused on the introduction of AI tools for human-AI collaboration [62, 68]. How these AI-enabled as well as other

Table 1. Overview of identified concrete challenges and pathways towards successful collaboration with bots and automation in collaborative community projects.

Challenges in bots and automation	Pathways towards successful collaboration
• Creators of bots can impose their preferences due to the power of automation. See Sections 4.1.1, 4.1.3, and 5.1.3.	• Institute central community oversight that can approve and halt automation efforts (akin to Wikipedia).
• Automation overrules the voice of community members without development skills. See Sections 4.1.1, 4.1.3, 5.1.2, and 5.1.3.	• Introduce community infrastructure to support collaborative automation efforts between community members and democratise bot operation.
• Automation across different communities of practice introduces disputes. See Sections 4.1.2 and 4.1.5.	• Extend the flexibility of bot operations to support the customisation of automation output towards the preferences of different communities.
• Challenging for both bot creators and the community at large to assess the exact effect of an automation procedure. See Sections 4.1.3, 5.1.1, and 5.1.3.	• Interactive 'staging' tools to highlight the impact of planned automation on existing data. Supports concrete discussions among all community members rather than a selected few developers.
• Data imports and automation of 'easy' tasks can result in 'collaborative deserts', preventing the uptake of new members. See Sections 4.1.2 and 4.1.4.	• Surfacing (sub-)tasks which cannot be completed through automation for validation and completion by new members (see Figure 3 for an example).

automated tools can work not only for individual users but integrate successfully into community-driven projects remains an under-explored area in the literature. We hope to inspire future work in this direction. Rather than only algorithmic accuracy, this requires a thorough understanding of the practices within a community and careful consideration of the power structures introduced through and reinforced by automation.

As Ceccaroni et al. point out, there are specific risks in the use of AI tools in citizen science projects [6]. For example, they note the risks of human-AI collaboration to user engagement when: (1) users do not get sufficient credit for their help, (2) the focus shifts to commercial purposes and appropriation in lieu of the social good, and (3) the burden of data work increases, such as with rights release and sharing agreements. To make AI tools work, they find that "*it is important that AI computing resources are openly accessible and available to all, creating opportunities for citizens to be involved in AI research and to understand how the data they collect are being used.*" [6].

6.4 Limitations

We recognise several limitations that should be kept in mind when interpreting our findings. First, our source of information on bots and automation (Section 4), as well as our recruitment of OSM contributors for the survey (Section 5), were limited to (a subset of) OSM mailing lists. Yet, there are several other outlets where discussions of OSM happen. This includes the wiki, the OSM forums, the OSM Slack, and OSM's own 'State of the Map' conference. Data from those sources is not as readily available, but might be able to provide distinct perspectives. We also note that both our analysis of the mailing lists and our survey announcement were limited to English-speaking countries. Prior work has highlighted the role of culture on crowd mapping behaviours [50], an aspect that we did not consider in our analysis. Further, we did not perform a temporal analysis of themes and it is therefore possible that concerns and opinions have shifted over time or that some issues have been resolved. However, the responses collected in our survey seem to indicate that this is not the case. The nature of our data collection similarly prevented us from investigating the role of demographic factors in the discussion and usage of bots and automation. Particularly the role of gender has been previously found to play a role in the way bots are used in OSM [9]. Second, our survey did not include any people who have previously dropped out of contributing to the OSM community. These former community members might hold valuable information, as automation might have influenced their decision to leave the community. Third, the OSM community's unique characteristics may limit our findings' applicability to other large-scale collaborative projects. Our findings, as well as other work [40], highlight the large degree of autonomy of OSM contributors due to a limited number of rules, a lack of central oversight, and an absence of community consensus on 'how' and 'what' should be mapped. In Section 6.2.1, we contrast the stringent processes that dictate the contribution of both humans and bots within the Wikipedia community [61]. The way automation interacts with other large-scale collaborative projects is likely to be impacted by unique characteristics specific to each project.

7 CONCLUSION

In this article we report on the experiences of contributors in online collaborative communities interacting with bots and automated edits, in the case of OpenStreetMap. Through the analysis of OSM mailing lists and a survey, we have identified challenges with automation in online collaborative projects as the result of challenges in alignment and consensus building, power imbalances, and the negative impact on community building. Meanwhile, our findings also point to the added value of automated edits in the maintenance of large-scale collaborative projects. Our work highlights both the overall need and specific opportunities for socio-technical tools to better support online collaborative communities in engaging with automated edits and bots. Specifically, we point to a need for higher accountability of bot creators, the ability to adjust or limit automated edits based on rules and guidelines of (geographical) sub-communities, and better tools to preview and discuss changes before they are carried out. By contrasting our results to prior work on automation within Wikipedia, we stress the impact of established organisational and technological practices on the challenges faced in embedding bots and automation in collaborative projects. While democratising bots and automation is key to all large-scale collaborative projects, the optimal process and outcome are likely to differ between communities.

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A OSM SURVEY

Demographic Information

- *What is your age?* — Freetext response; optional
- *How do you describe yourself?* — Choice of ‘male’, ‘female’, ‘non-binary/third gender’, freetext self-description, ‘prefer not to say’; optional
- *In which country do you reside?* — Selection from list of countries; optional

OSM Experience and Activities

- *For how many years have you been a member of the OSM community?* — Freetext response; optional
- *In which ways do you typically contribute to OSM?* — Choice of ‘contribute new map data’, ‘Resolve issue in existing map data’, ‘Report issues in existing map data’, ‘Develop software’, ‘Report issues with software’, ‘Maintain Wikis’, ‘Translations’, ‘Organisation of local community/chapter’, ‘Organisation of OSM globally’, ‘Promoting OSM’, freetext response; optional
- *Are you part of any OSM working groups?* — Choice of ‘Licensing Working Group’, ‘Data Working Group’, ‘Operations Working Group’, ‘Engineering Working Group’, ‘Communications Working Group’, ‘StateoftheMap Organising Committee’, ‘Membership Working Group’, ‘Local Chapters and Communities Working Group’, freetext response; optional
- *Do you make use of automated edits or bots in your own contributions?* — Choice of ‘Never’, ’Sometimes’, and ‘Often’
- *Do you encounter automated edits or bots from others in your mapping activities?* — Choice of ‘Never’, ’Sometimes’, and ‘Often’

Experiences with Others’s Bots and Scripts

This section was only shown if participants answered ‘sometimes’ or ‘often’ to the earlier question on encountering other’s bots and scripts.

- *What are steps you currently take when encountering bots or automated edits by others with which you disagree?* — Freetext response
- *Please describe, without considering any limitations, how you would ideally react to edits with which you disagree as made by others through bots or automated edits. Consider, for example, technological, community, or policy aspects that could help you in the best way possible.* — Freetext response
- *Please describe, without considering any limitations, what you believe others can do to ensure the contributions of their bots or automated edits are of value to the rest of the OSM community. Consider, for example, technological, community, or policy aspects.* — Freetext response

Experiences with Own Bots and Scripts

This section was only shown if participants answered ‘sometimes’ or ‘often’ to the earlier question on making use of bots and scripts themselves.

- *Please describe how you engage with the community before running your bot or automated edit on OSM.* — Freetext response
- *What, if any, are the challenges you face in assessing the correct behaviour of, or recovering from errors made by, your bot or automated edits?* — Freetext response
- *Please describe, without considering any limitations, how you would ideally prepare and evaluate your bot or automated edits. Consider, for example, technological, community, or policy aspects that could help you in the best way possible.* — Freetext response