Work-to-Rule: The Emergence of Algorithmic Governance in Wikipedia

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ABSTRACT

Research has shown the importance of a functioning governance system for the success of peer production communities. It particularly highlights the role of human coordination and communication within the governance regime. In this article, we extend this line of research by differentiating two categories of governance mechanisms. The first category is based primarily on communication, in which social norms emerge that are often formalized by written rules and guidelines. The second category refers to the technical infrastructure that enables users to access artifacts, and that allows the community to communicate and coordinate their collective actions to create those artifacts. We collected qualitative and quantitative data from Wikipedia in order to show how a community's consensus gradually converts social mechanisms into algorithmic mechanisms. In detail, we analyze algorithmic governance mechanisms in two embedded cases: the software extension "flagged revisions" and the bot "xqbot". Our insights point towards a growing relevance of algorithmic governance in the realm of governing large-scale peer production communities. This extends previous research, in which algorithmic governance is almost absent. Further research is needed to unfold, understand, and also modify existing interdependencies between social and algorithmic governance mechanisms.

Categories and Subject Descriptors

H.5.3 [**Group and Organization Interfaces**]: Collaborative computing, Computer-supported cooperative work, Web-based interaction; K.4.3. [**Computers and Society**]: Organizational Impacts, Computer-supported collaborative work

General Terms

Human Factors, Algorithms

Keywords

Wikipedia, governance, wiki, software, bots, qualitative

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1. INTRODUCTION

January 15th, 2013 was the 12th anniversary of Wikipedia's founding in 2001. This was again a day when the impressive growth of an open, collaborative project was celebrated. "More than 1.5 million people in almost every country have contributed to Wikipedia's 23 million articles," states Sue Gardner[1], the executive director of the Wikimedia Foundation. She stresses peoples' contributions to this peer production project by saying, "The more eyes on an article, the better it is. That is the fundamental premise of Wikipedia, and it explains why Wikipedia works."

Research on Wikipedia often follows the same perspective and looks primarily at human coordination and communication efforts for creating this free, collectively generated online encyclopedia. This perspective does not fully embrace the socio-technical nature of the project. The openness and stability of Wikipedia are only possible because of a "sophisticated technomanagerial system" ([20], [9]). We hypothesize that such a " technomanagerial" system rests on social and technical, i.e. algorithmic, governance mechanisms. The impact of algorithmic governance on the success of a peer production community has not been well researched yet [17]. With the following article, we aim to contribute to this emerging field of research by (1) characterizing social and algorithmic governance mechanisms, (2) discussing implementations of algorithmic governance mechanisms, and (3) presenting examples of how existing social mechanisms are successively manifested in the technical infrastructure by converting them into algorithmic mechanisms.

Our article is organized as follows. In the first part, we review existing research on governance in peer production communities in order to determine the essential building blocks of governance regimes in these contexts. We extend our literature review by summarizing works that specifically address technical implementations of governance, primarily by considering bots. In the second part of this article, we describe the transformation of social governance mechanisms into technical mechanisms based on qualitative and quantitative data collected from the Wikipedia project. We start by examining existing social governance mechanisms, and afterwards we describe two representations of algorithmic governance. The first representation is a specific MediaWiki extension of Wikipedia's underlying software. We highlight the influence of a small group of community members who introduce a new quality assurance system for articles. With the second representation we show how the community gradually transfers "rights to rule" to bots. In

[1] Sue Gardner in Los Angeles Times, January 13, 2013 (http://soc.li/uhtOs4Y)

our discussion, we claim that the importance of this algorithmic governance will grow disproportionally, even more as the number of Wikipedia articles continues to grow while the number of editors stagnates [27].

2. RELATED RESEARCH

In the first part of our literature review, we focus on the state-of-the art of research on governance in peer production communities in general and then specifically on Wikipedia. In the second part of this section, we discuss existing research in the realm of technically encoded rules within Wikipedia's governance regime.

2.1 Governance in peer production communities

From a strategic management perspective, Williamson defines governance as the creation of order to achieve mutual gains in potentially conflict-laden contexts [39]. Examples of commons-based peer production [1] such as open source software or Wikipedia are regularly characterized as self-organized, resource governance regimes ([29], [6]). A carefully negotiated and balanced set of rules is required to ensure the long-term survival of such commons-based governance regimes [22].

Questions related to the specificities of governance in the context of computer-mediated peer production have been mainly based on open source software (OSS) communities so far. In one of the earliest studies in this context, Shah identified different types of participants in OSS and noted that their level of participation is highly dependent on the implemented governance structure [25]. In open settings, the governance regime is a dynamic phenomenon. Research has shown that a community's perception of its governance regime may change over time [16]. For example, communities are likely to introduce bureaucratic mechanisms into a stabilized governance regime, which would have been unthinkable in earlier phases [21]. Despite these evolutionary aspects, governance can be conceptualized on different analytical levels (individual, project, inter-project) [13]. On an individual level, for instance, artifacts - to which certain activities are applied - are important in terms of their role as a coordination mechanism. Based on a synthesis of research on open source software governance, Markus suggests different components of a governance regime: "(1) structures and processes, (2) informal, formal, and encoded rules, (3) externally applied as well as internalized rules, and (4) mechanisms of both trust and verification/control" [18]. Although we find the distinction between informal, formal and encoded rules in Markus's discussion, the role of "encoded rules" is not further investigated.

More recently, scholars interested in the governance of large-scale peer production communities have turned increasingly to the case of Wikipedia. Existing assessments of Wikipedia's governance model are quite diverse. While some describe Wikipedia as an example of comparably egalitarian and participatory governance [14], other studies emphasize its bureaucratic features [4] or even define it as a "strict hierarchical content management system" [20]. An overview of all these different perceptions of governance in the context of Wikipedia is given by Schroeder and Wagner [24].

Butler et al. underline that the form of governance in Wikipedia has changed substantially over time; they observe a transformation from rather anarchic towards more bureaucratic forms of governance [4]. This aligns to similar observations in the OSS context (e.g., [16], [21]). In this regard, scholars examine the complex nature of policies and rules in the Wikipedia community and they provide different perspectives on these policies, guidelines and rules [4]. Butler et al. suggest that the perspectives of a governance regime can support the identification of policies that can be embedded in the technical infrastructure.

Most studies that investigate Wikipedia's governance regime focus exclusively on the group of human users when trying to model existing editing patterns (e.g., [3], [23]).

Although scholars describe communities and their governance as a socio-technical phenomenon, "[in] online communities, technology is the medium through which members act" [2] and "the potential for sophisticated, community-generated social norms and governance mechanisms is partly a designed feature of the technological architecture" [6], existing interdependencies between the technical and the social infrastructure are mentioned but not well-researched.

We extend this line of research by concentrating on rules[2] that have been embedded in the technical infrastructure of a community. One part of this algorithmic dimension of governance is bots. In the next section, we describe existing research on bots in Wikipedia, their role for Wikipedia's governance regime, and existing research gaps.

2.2 Encoded rules in Wikipedia's governance regime

Research on the socio-technical infrastructure of Wikipedia is often qualitative in nature, largely restricted to the English language version, and focused on bots (e.g., [7, 8, 12, 11]). Bots are "fully-automated software agents that perform algorithmically-defined tasks involved with editing, maintenance, and administration" [9]. However, bots are not exclusively interpreted as software tools but also as managerial protocols [20] that are part of the infrastructure [8].

It is argued that the majority of bots are not authors but that all bots can be seen as "content agents" [20]. This view has been extended by Halfaker et al. [12]. They define a taxonomy of Wikipedia bots that differentiates four types: (1) bots that transfer data from public databases (e.g., census data) into articles, (2) bots that monitor and curate articles, (3) bots that extend the existing software functionality of Wikipedia's underlying MediaWiki software (e.g., by converting an ordinary page into a dynamic, priority-based discussion queue), and (4) bots that protect against malicious activities.

Bots' activities are often hidden from human editors [7] because their edits are automatically filtered from the article history log. But the importance of these hidden activities is particularly apparent in activities such as banning malicious contributors to Wikipedia [9]. In an ethnographic study, Geiger and Ribes claim that the redistribution of work between human and non-human contributors also transforms the "moral order" of Wikipedia because the assessment of human edits is carried out mainly by automated or semi-automated tools [9]. Following this hypothesis, we assume that socially defined rules are empowered by converting them into infrastructure. This conversion then changes the nature of the embedded rules as well as their importance for regular users. Such an interdependency between a written rule that emerges from a shared community practice and its technological formulation has been shown in the single case study of the HagermanBot [8]. The

[2] We are aware of existing differences between policies, guideline and rules, but in this article, we use these terms interchangeably.

HagermanBot adds a user's signature to unsigned discussion posts. Geiger illustrates how, during the course of bot operations, the requirements made upon the algorithmic formulation of social norms have changed. People were upset about the bot signing their deliberately unsigned discussion posts. Geiger identified this as one reason for the opt-out mechanism for bots then introduced [8].

In a nutshell, although scholars emphasize the significance of bots for Wikipedia's governance regime, it is only investigated marginally how algorithmic rules emerge from written formats that are based on community consensus. Existing studies focus exclusively on bots. Knowledge of which types of rules are governed by bots, as well as the existing consequences of implementing these rules in bots is still missing.

3. SOCIAL AND ALGORITHMIC GOVERNANCE

Summarizing the results of our literature review, we can distinguish two groups of mechanisms that support governance in peer production communities - social and algorithmic governance mechanisms.

The first group comprises mechanisms that are based primarily on social information. Contributors need social information to define their role in a peer production community as well as to understand existing norms, policies, and procedures that are needed to carry out tasks (e.g., [28], [19]). Thus, we specifically emphasize mechanisms that support communication in terms of an informal organizational structure and mechanisms that relate to the formally defined organizational structure. As we have shown, this type of governance regime is well researched in the OOS and Wikipedia context (e.g., [21], [4], [24]).

The second group relates to algorithmic mechanisms that are based on informal or formal rules that have been converted into algorithmic instructions. OOS research focuses on technical artifacts such as standards, architectural documentation, and the API descriptions that are needed to perform design-related tasks (e.g., [10], [5]), whereas research in the Wikipedia context is mostly related to bots and their role in the production-based community.

Both types of mechanisms have their inherent, distinguishing characteristics. For example, algorithmic mechanisms scale up well but social mechanisms do not. On the other hand, social mechanisms handle exceptions better than technical mechanisms do (e.g., [21], [8]). At the same time, algorithmic mechanisms ensure that arbitrary behavior can be reduced, for example in terms of this handling of exceptions.

In the research presented in the following, we adopt this differentiation by describing different strategies of converting social governance mechanisms into algorithmic mechanisms and highlighting their complementary characteristics.

4. RESEARCH METHOD

In the first phase of our research, we sampled Wikipedia because of our prior interest in bots. Previous studies on bots are based almost entirely on the English language version. In order to assess the universality of this phenomenon, we decided to compare the findings of these studies with another language version, i.e. the German Wikipedia. The German Wikipedia is the second largest language version, which had an even ratio of 1.5 million encyclopedic articles and authors (in the English Wikipedia the ratio is 1:4.5) in December 2012. While the overall development of the German version of Wikipedia follows a similar impressive pattern to its larger sister project, we found substantial differences with regard to the implementation of algorithmic governance mechanisms, as we show in the following.

During the second phase of our research, we collected ethnographic and archival data from various sources. We manually checked about 500 user pages, which allowed us to classify existing bots in Wikipedia. Additionally, we investigated about 100 policy-, discussion-, and bot-management-pages in the German and English Wikipedia. Apart from that, we collected bot data (primarily edit history logs) from the Toolserver[3] as well as the MediaWiki API[4].

In the third phase, we dealt with the data analysis. For this, we combined our qualitative and quantitative data. For example, the manual inspection of user pages of active bots enabled us to classify the edit summaries of bot edits. We arranged data collected from discussion and policy pages in a temporal order, to reconstruct the decision-making process of the community. Moreover, we interviewed one active Wikipedian to verify our insights.

5. RESULTS

In this section, we describe our research results by looking especially at the role of algorithmic governance mechanisms in Wikipedia and their interrelatedness to social mechanisms. For this, we analyze community level procedures that evaluate and decide on the implementation of algorithmic forms of governance. Then, we look at algorithmic governance mechanisms that are integrated into Wikipedia's technical architecture. Finally, we show how bots, algorithmic tools originally implemented to support content creation, are being used increasingly for governance purposes.

5.1 Community level

Historically, the Wikipedia community has been reluctant to establish binding rules for (potential) editors. As a result, policies "that all users should normally follow" as well as guidelines that "outline best practices for following those standards in specific contexts" are not considered to be "hard-and-fast rules" [37]. All rules and guidelines are collected in a special area of the Wikipedia project – the so-called Wikipedia namespace. In 2007, Butler et al. counted 44 pages in the "official policy" category and 248 in the "Wikipedia guidelines" in the English Wikipedia [4]. About five years later (end of 2012), the number of pages in the policy category had increased to 383 and in the guideline category to 449 respectively. Even though Wikipedia's community shows reluctance towards rules, the number of defined rules has increased over the years. The governance regime in Wikipedia is still evolving, and in the following we show that algorithmically formulated rules are involved as well.

The notion of Wikipedia as a democracy is rejected explicitly [35] it nevertheless offers democratic tools such as surveys and polls. While the former should mostly help to gather knowledge about the community and different usage practices, the latter are used in the course of decision-making processes. Attitudes towards polling vary between the different language versions. In the English Wikipedia, for example, the respective page is not simply entitled "community's opinion" as in the German version ("Meinungsbilder");

[3] http://toolserver.org/

[4] http://de.wikipedia.org/w/api.php

instead, the title is "Polling is not a substitute for discussion". Consequently, the description emphasizes that "most decisions on Wikipedia are based on consensus, not on vote-counting or majority rule".[38] This fundamental skepticism towards strict rules extends to the sphere of rule-making and rule enforcement, as well as where consensus should be sought, and a majority of votes is not generally considered enough to legitimize decisions.

In the context of algorithmic governance, polls, i.e. "community's opinion", are particularly noteworthy as a means of determining consensus with regard to (1) implementing algorithmic mechanisms or (2) defining criteria for accessing them. An example of a dissenting community opinion is automated vandal fighters. In the German Wikipedia community, these bots are not permitted. Such algorithmic tools are only intended to support editors in identifying possible malicious edits, but automated assessments are not accepted. Fighting vandals is seen as a form of handling exceptions and should therefore be based upon human evaluation. Conversely, in the English Wikipedia bots such as the MartinBot[5] are accepted for their activities and research has shown their importance for community processes [9].

Existing cultural differences and preferences are not only expressed as different choices about whether to introduce algorithmic mechanisms but also about the extent to which this algorithmic mechanism is adopted. For example, polling led to continuation of the "Flagged Revisions" software feature on the German Wikipedia in 2008. As opposed to the English Wikipedia, where the "Pending Changes" tool was introduced after lengthy discussions in December 2012 [36]. It can be interpreted as a simplified version of the "Flagged Revision feature". Consequently, social versus algorithmic governance mechanisms feel quite different to participants, and they may have fairly strong preferences – preferences that may differ by community or regional culture.

In the next section, we look at Wikipedia's technical architecture and its relation to the governance regime.

5.2 Software features

Wikipedia's technical architecture is based on the MediaWiki software that is maintained by the Wikimedia Foundation. Not only Wikipedia uses the MediaWiki software. The other nine sister projects of the Wikimedia Foundation, such as Wiktionary, Commons, and Wikibooks and countless independent wiki projects also employ this software. For each Wikipedia language version, basically the same MediaWiki core and a selected set of extensions are used. The software is very adaptable and allows for adding or changing an extensive number of features based on more than 700 configuration settings and almost 2,000 extensions.

Each language version of Wikipedia has its own customized configuration settings as well as integrating its own set of extensions. This software flexibility can lead to quite different software feature sets in each language version. By community consensus (cf. previous section), new functionality can be added to one specific language version of Wikipedia. The Wikimedia Foundation tries to keep the differences between each version as small as possible because this reduces the complexity of maintaining different software versions. As in the case of the "Flagged revisions", where the extension was initially introduced in the German version and later the other language versions followed. In each language version, it was mainly the community that decided on the configuration parameter of this extension.

Currently (January 2012), 72 additional extensions are integrated into the German Wikipedia alone; in the English Wikipedia, we counted a total of 83 different extensions.[6] The difference is mainly caused by extensions that are used in English Wikipedia for testing. For example, one extension is a toolkit that allows Wikimedia employees to run experiments on editor engagement[7], or the "Page Triage" extension[8] is a new feature for curating new articles.

In a way, software features represent the "hard law" of Wikipedia [17]. While policies and guidelines may be ignored and users are explicitly pointed to the fact that "there will be occasional exceptions to these rules" it is much more difficult if not impossible to ignore rules implemented in the form of software functions. When people use MediaWiki for coordinating their collective efforts, they depend on functions provided by the software. These functions can enforce people to adopt a specific behavior or procedure in order to get things done. Moreover, the utilization of specific functions is often restricted to a specific group of users. For example, users who belong to a specific user group can access the rollback feature in the English Wikipedia.[9] These so-called "rollbackers" can undo unwanted edits very fast with one click. By converting the social rule of deleting vandalism, for instance, from an article, into an algorithmic mechanism, the span and speed of reverting edits has been accelerated.

Criteria that define which user can access a feature are again provided by community consensus. As a result, governance via software features might also be subject to substantial change over time.

For illustration purposes, the following subsection presents the example of Wikipedia's flagged revisions feature to show how community consensus converts existing social norms into a software feature. As opposed to the rollbacker function, where access to the feature is granted by an administrator's decision, access to the flagged revision feature in German Wikipedia is mostly given automatically.

5.2.1 Example: Wikipedia's flagged revisions feature

The concept of "Wikipedia's flagged revisions feature" (cf. Figure 2) is described in the English language Wikipedia as

> *"a system whereby users who are not logged in may be presented with a different version of an article than users who are. Articles are validated so that they are presentable and free from vandalism. The approved versions are known as sighted versions. All logged-in users will continue to see and edit the most recent version of a page. Users who are not logged in will initially see the most recent sighted version, if there is one."*

[34]. In 2006, the idea of having a more reliable quality system for articles on Wikipedia was discussed publicly for the first time

[5] http://en.wikipedia.org/wiki/User:MartinBot

[6] http://en.wikipedia.org/wiki/Special:Version

[7] http://www.mediawiki.org/wiki/Extension:E3_Experiments

[8] http://www.mediawiki.org/wiki/Extension:PageTriage

[9] http://en.wikipedia.org/wiki/Wikipedia:Rollback_feature

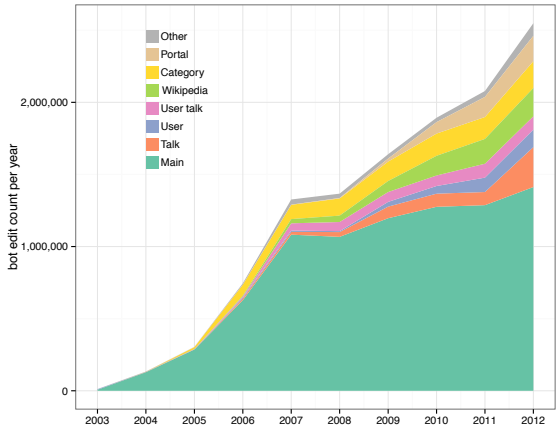

Figure 1: Development of bot edits in each namespace over time. The following namespaces (with edit counts in parentheses) has been aggregated to the category "other": Template (96,455), File (73,449), Wikipedia talk (54,724), Portal talk (36,459), Template talk (2,202), Help (1,023), Category talk (502), File talk (344), MediaWiki talk (299), MediaWiki (278).

during Wikimania[10]. Over the next two years, a small group of German Wikipedians took the lead in developing the flagged revisions feature[11] as a measure to secure against vandalism and improve article credibility. In May 2008, after an official statement by one Wikimedia representative, the feature was introduced to the German Wikipedia as a trial. Almost at the same time, various surveys started asking the community for sighting criteria, for instance, or about their general agreement to this feature. Three months later, a "community's opinion" poll was initiated. This was actually the first time that the broad community had been involved in the decision about using this algorithmic mechanism. One month later the community reached consensus on continuing with the feature [30].

Figure 2: Screenshot of "Flagged revision" extension in action.

Since its introduction to the German Wikipedia, the concept has evolved into a complex set of rules determining who can sight Wikipedia edits. During the testing period, only admins could receive a reviewer status. Every other user had to apply for a reviewer account. This system was replaced by a simple threshold of 30 edits and 30 days registration period. Further discussions led to a more sophisticated set of criteria. As of today, the German Wikipedia distinguishes two types of reviewers: active and passive reviewers. To become a passive reviewer, the user has to fulfill six criteria (e.g., at least 150 edits on eight different pages in the article namespace). The rules for becoming an active reviewer follow a similar logic, but the standards are even higher. Active reviewers earn the additional privilege of accessing the rollback feature.

Whereas access to this governance feature is restricted socially on the English Wikipedia, the German language version grants this particular right automatically. Editors who do not (yet) meet the required criteria on German Wikipedia can apply to get reviewer rights. In other words, human evaluation has turned from the rule to the exception when it comes to the flagged revisions feature.

The whole system now works mostly automatically, which is why many if not most editors receive reviewer status without having to know anything about the concept of sighted revisions. As a result, access to the flagged revision feature scales up better than systems of manually assigning roles such as the rollbacker user right in English Wikipedia. While assigning rollbacker rights requires trust building among editors, the flagged revisions feature replaces human evaluation with a mere algorithmic processing of pre-defined criteria.

5.3 Bots

In Wikipedia, bots are described as programs or scripts that help their operators to carry out "mindless, boring and often reoccurring tasks" (e.g., typo corrections). Similarly to human users, bots have their own user pages that contain amongst other things the name of the operator, a description of their tasks, and a link for administrators to shut them down if needed.

By assigning a bot flag to a registered user account, the user is made a member of another user group that has more rights. For example, bots have no edit limits, they are allowed to work on semi-protected pages[12] and their edits are automatically patrolled and reviewed (cf. previous section). The operator only has to consider some restrictions by implementing the bot, such as a speed reduction of maximal five edits per minute.

Basically, every registered user on Wikipedia can apply for a bot flag. But the status is only granted if specific requirements are fulfilled, such as the user name should contain the word "bot", a specific bot template has to be included on the user page, the bot should provide some successfully carried out sample edits, and the application for a bot flag has to be announced to the community. Additionally, bots should only operate in the main namespace, i.e. the space of Wikipedia that contains all encyclopedic articles. Exceptions are possible, but these have to be discussed with and agreed to by the community. Such a discussion has to occur within seven days; otherwise, bureaucrats grant the bot flag if there are no other impediments. From 2008 to 2012, 221 users applied for a bot flag, 38 of those withdrew their requests, and in only 35 cases, the community voted against their ratification.

In December 2012, the German Wikipedia had 353 users with a bot flag assigned. These bots have been responsible for 12,183,766 edits (mean=35,410, std. dev=93,502.02) in the last 9 years. This corresponds to the number of edits carried out by the most active human users in December 2012 (13,747,466 edits, mean=38,945, std. dev=48,089.02).

In the first step of our analysis, we focus on the areas of bots' editing activities. Figure 1 shows all bot edits in each namespace over time. Namespaces in Wikipedia can be seen as an ordering system that refers to page types. Besides the main namespace that contains the encyclopedic articles, there are 21 additional spaces that contain, for example, user pages, templates and the aforementioned community pages. Despite the often referenced decline of contributions by human editors [27], edits carried out by bots are

[10] Wikimania is an annual, global community conference for all Wikimedia projects.

[11] http://www.mediawiki.org/wiki/Extension:FlaggedRevs

[12] Semi-protected pages can only be changed by users that have been registered at least since four days.

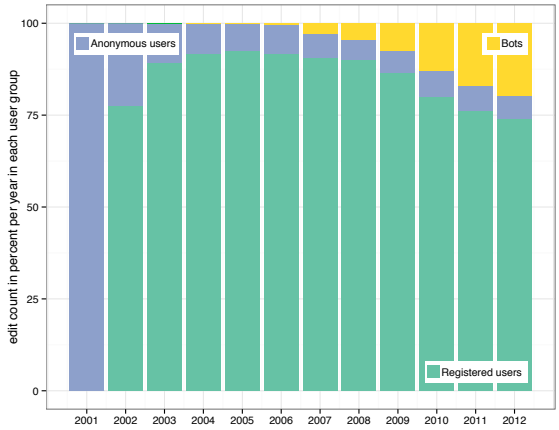

Figure 3: Development of edits per user group (registered user, anonymous user, bot) in the Wikipedia's administrative namespace 4.

continuously increasing in number. Since bots have shown their usefulness for a wide variety of tasks in the main namespace, their scope has steadily expanded, and more edits have taken place in other namespaces.

This contradicts a community guideline that suggests the avoidance of editing activities of bots outside the article namespace. However, in 2012, these "outside" edits accounted for over 40 percent of all bot edits. This emergence of bot activity all over the community project is an indication of the growing importance of these "little helpers" for the community's activities. This relates to a study that analyzed the diversification of human edits over the different namespaces. In 2001, about 90 percent of all edits were carried out in the article namespace, but in 2006, this number had already decreased to 70 percent [15]. We assume that the change in the community engagement of bot operators also expanded the reach of bot edits. More interestingly, while human edits slowed down in Wikipedia's community space, edits carried out by bots increased as shown in Figure 3. In this administrative space, 20 different bots have been active on average (disregarding wikilink-bots).

In the next part of our analysis, we specifically look at the types of activities bots carry out. Our interest is twofold: first, we classify tasks executed by bots in order to understand their relatedness to existing social governance mechanisms. Second, we examine our assumption of increasingly algorithmic rule enforcement by bots.

We collected task descriptions from bots' user pages to examine the kinds of activities in which bots are participating in the Wikipedia community. In single, doubtful cases we matched edits with their task descriptions to identify discrepancies and exclude those activities. Based on these data, we defined general activity types that are indicated in the first column of the table 1. These general activity types were defined in three steps. During the first round, we coded existing task descriptions collaboratively (around 100) until we had an almost stable set of activities. In the second round, we separately coded the remaining task descriptions. In the third round, we checked the assigned codes and compared them with our own decisions, and collaboratively coded all task descriptions that needed new activity types. In order to create a shared understanding of existing activity types, the second and third rounds were an iterative process. Newly introduced activity types were always cross-validated over the whole data set.

We clustered the manually defined sets of activities in activity types (cf. second column of the table 1) and identified three foci of bot activities (cf. fifth column of the table 1): (1) the *content* focus, (2) the *task* focus, and (3) the *community* focus.

The first category contains mainly bots that are active in the article namespace. These bots are created primarily to support the curating activities of their operators (for example, by using Autowikibrowser – a semi-automated MediaWiki editor[13]) or to connect different language versions of a page through interwiki-links. The second category comprises bots that are used to support the maintenance work of editors by compiling working lists or by informing editors about existing status changes on articles. The third category - the community focus - refers to activities that are rather unrelated to encyclopedic articles; they are more related to community rules and their enforcement.

Four bots have a community focus: the CopperBot, GiftBot, Itemsbot and xqbot. The CopperBot is the German equivalent to the HagermanBot of the English Wikipedia [8] that is responsible for signing unsigned comments on discussion pages. The main task of the Itemsbot was welcoming new users to the German Wikipedia by leaving a message on their personal discussion pages. Probably because of the aforementioned community consensus against bot welcome messages, the bot stopped working within two months. In 2008 and 2009, the operator of the Giftbot requested a bot flag for her bot in order to correct spelling mistakes. In both cases, the request was denied. In July 2010, the third request was successful. This time, the bot tasks included the removal of processed flagged revision requests, the dissemination of a newsletter that contains information on new edits on pages such as polls, and requests for banning users as well. All these activities were much more focused on specific community needs. We assume that the operator of Giftbot learned much more about existing rules and guidelines over time and was therefore much better able to meet the needs of her fellows.

The last of the four community bots is introduced in more detail in the next section. We show in an exemplary way how the activity set employed by this bot changes over time.

5.3.1 Example: xqbot

In October 2008, the editor applied for a bot flag for her xqbot in order to request speedy deletions of orphan pages[14] or remains of moved pages. In November 2008, the bot flag was assigned and the bot started working. Soon after this, the bot activities included over ten different tasks such as correcting double redirects, fixing links on disambiguation pages, adding missing references tags in articles, and the setting of interwiki-links. All these tasks were mainly focused on quality improvements to encyclopedic articles. In 2010, the focus changed in terms of additional tasks. This was motivated mainly by a procedural problem that occurred during an administrator re-election.

In January 2010, one participant initiated a discussion by questioning the procedure to take care of obsolete votes [31], [32]. The

[13] http://en.wikipedia.org/wiki/Wikipedia:AutoWikiBrowse

[14] Orphan pages on Wikipedia are articles that have no or very few incoming links.

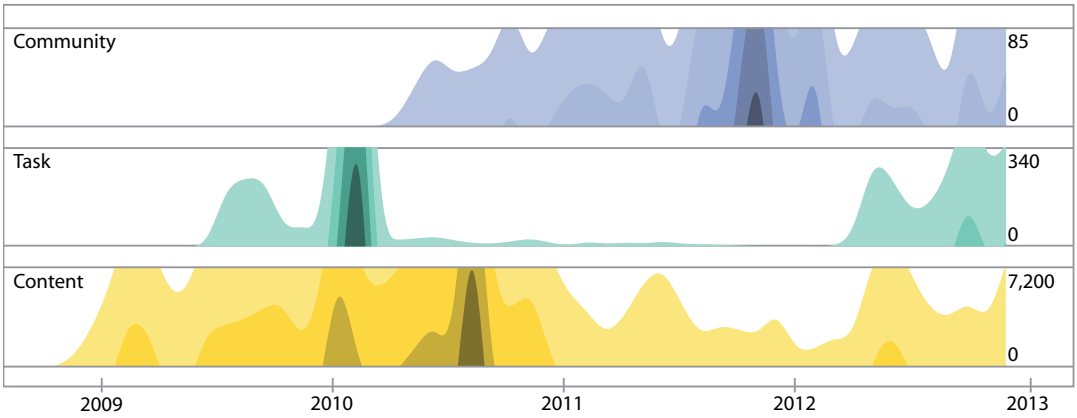

Figure 4: Horizon graphs are showing xqbot's extending activity focus over time - starting with an content focus, including more maintenance activities (task focus) into the portfolio and increasingly supporting the Wikipedia community (community focus).

complex set of rules for administrator re-election on the German Wikipedia states that an administrator is automatically re-elected if users with voting rights (25 within one month or 50 within six months) support this re-election request. Votes are only valid if they are submitted (by signing a page) in one of the two possible periods of time. The decision to simply remove the outdated votes led to a user complaint. In the course of this discussion the idea emerged to use a bot for excluding obsolete votes in the final vote counting process. One of the participants of the discussion asked for this feature on the bot request page [33]. This request accelerated the discussion on the re-election page and within a few hours over 20 people participated in a discussion that mainly centred around the question whether obsolete votes should be removed or not. The final community consensus was to delete these votes and one bot operator agreed to incorporate this task into her software. The implementation details of the rule (on a meta-level) were only discussed between the requester and the bot operator. Finally, in April 2010 the xqbot started to delete obsolete votes from re-election pages and carried out almost 4,000 edits (cf. Figure 5 that shows one exemplary edit message). Meanwhile, xqbot extended his vote checking ability to other areas of application such as polling, requests for an administrator role, and *Arbitration Committee* elections.

• 18:03, 1. Jan. 2013 (Unterschied | Versionen) . . **(-881)** . . **K** Wikipedia:Adminwiederwahl/Michail *(Bot: Stimmberechtigung geprüft, abgelaufene Stimmen entfernt.)* **(aktuell)**

Figure 5: Example of an edit summary of the xqbot
In English: "*Bot: Checked voting rights, obsolete votes are deleted.*"

The xqbot translates community consensus into practice, initially for one selected case, but later this practice was transferred into similar areas without requesting additional community consensus. The ability of algorithmic governance mechanisms to be replicated easily in various areas of application has led to their increased and almost unnoticed enforcement of rules. At its inception, the xqbot was almost entirely focused on quality assurance of articles but this has been changed over its lifetime. In order to check these insights, we classified all edit summaries of the xqbot based on our specified coding scheme (cf. previous section). Figure 4) underlines our results by showing this gradual change of the activity focus.

6. DISCUSSION

Even though scholars consider the existence of technologically embedded governance mechanisms as a result of "encoded rules" [18], their characteristics and relatedness to the social governance regime of a peer production community is rather underrepresented in their discussion. This research is one of the first attempts to systemize this research by differentiating two basic types of governance mechanisms. By doing so, we are able to capture the opposing natures of these mechanisms.

The community discussion around implementing the flagged revision system shows the difficulties that arise from finding consensus on defining the "correct" version of an article. A manual revision of an article allows for applying a complex human-based rules system, but the implemented algorithmic counterpart is much simpler. One reason might be the challenge of formulating the complex decision-making process of humans in formal instructions. Humans handle exceptions by far more effectively and reliably. Another reason might be that community consensus is often based on the smallest common multiple. At the moment, Wikipedia's community seems to decide more intuitively about the implementation of governance mechanisms in a social or algorithmic design. A comparison of multiple social-algorithmic-rule-transformations might reveal a finer-grained rule set. However, the flagged revision case shows both the limitations of converting social into algorithmic governance mechanisms and the potentials in terms of scalability.

In a similar vein, the xqbot example shows the implementation of an algorithmic governance mechanism for one particular case. Without seeking further community consensus, the xqbot deletes obsolete votes from many more elections than originally suggested. This underlines the scalability of technically defined rules, which makes it much easier to apply them to additional areas of applications.

On the German Wikipedia, the "Flagged revision" extension has been developed by using predefined guidelines based on community consensus. The extension is now part of the standard set of available software features in each language version. Each of Wikipedia's language versions can now decide whether to apply it or not. Although other communities might have no need to use such mechanisms, we argue that their mere availability increases the

likelihood of their usage. (One reason for this assumption might be the still quite technocratic nature of the Wikipedia community.)

In both cases of algorithmic governance - software features and bots - making rules part of the infrastructure, to a certain extent, makes them harder to change and easier to enforce. The only chance to refuse bot edits on personal pages is to explicitly adopt an opt-out mechanism [8]. Bots change the nature of rule enforcement by putting them on a predefined schedule. The conversion of socially developed rules into source code makes norms even less transparent because only a small group of users can read source code [26]. Additionally, users take bot edits for granted, and they do not question them, which is reflected in their absence from the article edit log (in the normal mode).

The increasing development of algorithmic governance mechanisms calls for a good match between types of rules and their implementation strategies. We suggest that different kinds of rules should be implemented differently in the community's algorithmic governance regime, as already recommended by Butler et al. [4]. The growing importance of comparably rigorous algorithmic mechanisms of governance in Wikipedia is at odds with the rule-skepticism predominant among community members when non-technical policies and guidelines are concerned. However, one might wonder whether the rigidity of algorithmic rule-enforcement is the precondition to continued flexibility – if not laissez-faire – in the realm of community-level governance. Rules embodied in software features or bots provide a reliable basis for more or less controversial practices of collaborative content creation.

7. LIMITATIONS OF THIS RESEARCH

Even though we carefully prepared and carried out this research, we are aware of existing limitations and shortcomings.

First of all, our analysis is based primarily on one selected representative of a peer production system, the German Wikipedia. As shown in our discussion, the community's conception of the governance regime and the implemented social and algorithmic mechanisms differ in Wikipedia's language versions. We can show that algorithmic governance exists in the case presented, but our insights need to be validated by additional data in other language versions.

Second, our main line of argumentation is based on a sample of 353 bots that had a bot flag assigned in December 2012. Bots without an assigned bot-flag appear as "normal", human users. In future research, we plan to extend our data set by all users that contain the word "bot" in their user names (with probably manual detection of their real status).

Third, our main knowledge of the evolutionary nature of algorithmic governance is based on a manual coding scheme. To let other researchers reproduce our analysis, an automatic coding scheme that is based on pattern matching algorithms might be more suitable.

Finally, in our study we disregarded tools such as Twinkle and Rollback. These tools support users in their editing tasks by showing context-sensitive buttons and links to Wikipedia's user interface. We plan to extend our research by categorizing software functionality supported by these assisted editing programs [7].

8. RESEARCH IMPLICATIONS AND CONCLUSION

Impressed by the growing number and diversity of policies and guidelines governing collaborative content creation on Wikipedia, researchers seem to have lost sight increasingly of the governance structure constitutive of the Wikipedia community in the first place: wiki software features and integrated algorithms.

However, not only social norms and rules have changed and grown over time but the level of algorithmic governance - represented by software features and bots - as well. Even though "change rules" in infrastructure are differentiated by scholars (e.g., [18]), their forms, appearances and reasons for their implementation have been disregarded in the academic discussion.

Our research addresses this gap by showing how, in addition to social governance mechanisms, a growing number of increasingly complex forms of algorithmic governance measures are implemented directly into the technological infrastructure. Such algorithmic governance differs from conventional policies and guidelines in at least two regards: first, algorithms tend to work behind the backs of the editors; reviewer rights are awarded without editors even noticing it and edits made by bots do not necessarily appear in a page's version history. Second, algorithmically implemented rules are enforced automatically and can therefore be considered the "hard law" of peer production communities; while human editors are encouraged to "ignore all rules", non-human bot editors literally "work-to-rule".

Both these issues lead us to conclude that with the growing importance of algorithmic governance there is also a growing need to govern algorithmic mechanisms. Preconditions to such a more reflexive approach are algorithm transparency and regular reviews of (potentially unintended) outcomes associated with algorithmic governance (cf. e.g., [11]). These kinds of governance considerations should be taken into account when designing the technical architecture that will support online production communities. The MediaWiki software, for example, could make it easy to access all the kinds of data that bots might need. Or, for privacy reasons, it could make it impossible to access certain kinds of data. In general, the architecture of a system determines what is easy to change and what is difficult to change. Architectures for online production systems should be designed to give maximum flexibility for governance options. If a given bot is too difficult to implement, then that particular bit of governance can only be accomplished socially.

Our understanding of successful configurations of social and algorithmic governance mechanisms needs to be deepened. At the moment, our conclusions derived from the data are rather speculative in nature. As shown by Geiger[8], social and algorithmic governance mechanisms co-evolve. However, the impact of the algorithmic rule is difficult to anticipate in advance. An ethnographic research approach grounded on quantitative data is needed to extend our understanding of existing reciprocal effects and to derive design parameters for the building of software functions that more adequately support peer production community processes.

Additionally, looking at algorithmic governance should not be restricted to peer production communities such as Wikipedia alone. The anticipated importance of this phenomenon can also be studied in other social spheres such as online games.

activity type	# bots	activity cluster	# bots	focus	# bots
check syntax	62				
edit language	17				
add template	25				
update template	30				
add data	6				
update data	7				
archive article	5				
check for spam	1	editing articles	95		
set interwiki-link	249				
create content list	28				
link disambiguation	1	organizing articles	273	content	341
inter-bot-cooperation	1	supporting other bots	1		
create to-do list	18				
send to-do alert	6				
compile statistic	4	supporting editors	21	task	22
enforce rule	1				
welcome user	1	supporting communication	2		
support election	2	support decision-making	2	community	4

Table 1: Coding scheme defined by activity type using bot description pages of 353 user accounts with a bot flag assigned. Some bots carry out more than one task; so they are assigned to more than one activity type.

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