Chapter 8
Assessing the Structural Fluidity of Virtual Organizations and Its Effects

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Abstract A major advantage of Virtual Organizations (VOs) is flexible membership and participation. VO members are able to join and leave VOs at will, and can change whom they collaborate with at any point in time. Such flexibility may make VOs more efficient in the completion of collaborative work than traditional organizations. However, efficiency is only one of several measures of organizational performance; and flexibility in a virtual organization includes both how VO structures may be more fluid and adaptive, and how VO leadership emerges and evolves throughout the VO lifecycle. The aim of this chapter is to: (1) define and quantitatively assess the actual flexibility of participation in VOs, through a social network index that we call structural *fluidity*; and (2) measure the relationship between fluidity and performance in the work carried out within the VO. These are essential insights for the development of theories to guide the formation, development and dissolution of VOs, and teams that emerge around VO work. To accomplish these aims, we will apply a methodological approach and ontology for the study of VOs that we have used in over a dozen published studies, and refer to as Group Informatics. Our approach enables a comprehensive, interdisciplinary inquiry into the relationship between structural fluidity and performance in diverse VOs. Specifically, we will examine VOs in software engineering, disaster relief, online learning and public discourse communities that emerge through social media. We will apply Group Informatics to the design, development and testing of empirically and theoretically grounded algorithms for measuring VO fluidity and performance in each context, which will result in new theoretical advances that enable sophisticated analysis of the resulting data.

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8.1 Introduction and Motivation

One of the contexts of human activity that has been most deeply impacted by the prevalence and ubiquitous presence of Information and Communication Technology (ICT) has been without doubt the workplace. This is hardly new or surprising, since it had been predicted for decades that “office automation” would represent one of the first areas where computerized tools would fulfill their potential, and would revolutionize habits and practices.

Besides bringing along tremendous gains in individual productivity, the ICT revolution has also profoundly changed the concept of the office as an *organizational locus*. It has introduced ever-increasing degrees and sophistication of Computer-Supported Cooperative Work (CSCW); with that it has enabled the breaking of the physical, geographic and firm boundaries, and has helped construct novel technology-supported contexts for coordination and teamwork, which can be created ad hoc to help collaborators to get together and get things done. This is the promise of *Virtual Organizations* (VOs), and, in recent years, we have witnessed the rise of VOs in a large number of different domains, ranging from software engineering to education, and disaster response.

Virtual Organizations (VOs) have flexible membership and participation, as the barrier for members to be able to join and leave a VO is very low (in many cases they can do so at will); moreover, members can adapt with respect to whom they collaborate with at any point in time [52, 37]. This potential for flexibility is regarded as an intrinsic characteristic of VOs, and a differentiating factor vis-à-vis more traditional types of organizations. From such flexibility should descend that the organizational structure that can be observed in a VO can be more fluid than that of a traditional organization.

With this chapter we define the concept of *structural fluidity* of a VO in a way that can be measured quantitatively. Intuitively, structural fluidity is an easy concept to grasp, as an indication of participation, role and leadership changes within the organization over time. The reason why structural fluidity is an important concept to quantify and investigate lies in one of the basic assumptions underlying the interest in VOs, that is, that the flexibility implied by higher degrees of fluidity is an advantage. More specifically, one major expectation is that the greater structural fluidity in VOs is accompanied by higher performance in the completion of analogous work, when compared to more traditional forms of organization [4, 55, 58]. This extends from established understanding of the relationship between higher organizational adaptability and higher likelihood for an organization to survive over time [10].

However, the relation between indicators of structural fluidity and organizational performance has not yet been carefully examined, or proved. In fact, categorical and static qualifications of “how virtual” a VO is are discussed in the literature (based on a composite of attributes such as time zone difference, geographic dispersion, culture and work practice differences), but are **not** sufficient, *per se,* to explain variations in VO performance [11].

Our research agenda on the topic of structural fluidity is articulated according to a twofold objective: (1) develop methods to quantitatively assess the flexibility of VOs by means of the definition of an index of the structural fluidity of an organization. (2) investigate relationships between said fluidity index and context-specific performance indicators for the work carried out within such VOs.

A quantitative index of structural fluidity could shed light on whether VOs tend to be indeed more flexible than comparable traditional organizations, and to differentiate among diverse VOs designs and categories, in terms of their observable flexibility in allowing and accommodating structural changes. Furthermore a structural fluidity index would enable us to observe whether there are significant relationships between structural fluidity and performance. That is the ultimate goal of this kind of research: performance analysis is one principal application of a fully developed theory of Virtual Organizations [59], since it would provide a much needed insight to further the development of theories, practices and tools to guide and support the life cycle of VOs throughout their formation, development and dissolution.

8.2 Approach Outline

In this Section, we briefly introduce the challenges of investigating structural fluidity, and outline how they can be addressed.

We maintain that a foundation for the investigation of structural fluidity is the analysis of electronic traces that are made available by VOs by their very nature, since they can be captured and persisted from the collaborative tools that enable VO members' behavior. Studies that leverage those traces abound; among them, [9, 23, 26, 27, 32, 40, 57] offer some demonstrative examples of analyses that can be applied – and of insights that can be gleaned – which are similar to some techniques we envision to investigate structural fluidity.

Whereas, as we discuss further below, trace-based measures of performance tend to be context-specific and must be adapted to the work domain of each VO, we conceptualize a structural fluidity index as a composition of four general characteristics, which can be all made available from *the social network* fabric of a VO. One major characteristic we identify is leadership and, more precisely, **changes in leadership**, since at specific junctures a flexible VO can promote the rise of different leaders in different organizational positions, and exercising different types of leadership. Furthermore, the measurement of fluidity will also include **macro-properties of the VO** and its social network, including size, group count, and membership volatility. We will also take into account **trends over time of those macro-properties**, for instance, the participation trajectory of the VO, since a VO that tends to accommodate more and more new members is likely to provide for greater opportunities of diverse and emergent collaborations. The last characteristic denoting VO fluidity is a micro-property which becomes evident at the local level in the network, that is, the **variability of the ego-network** of each VO member at different moment in times, since we postulate that a high level of fluidity of the VO results in more free movement of its members in between and within smaller groups (both formal and informal), which in turn effects the variability of the members' "neighborhood".

Although all of the above properties can be analyzed by leveraging electronic trace data of interaction and work, there are several challenges associated to that kind of socio-technical analysis. First, the electronic trace data alone is not usually a complete record of participant interactions [34, 28, 29, 30]. Second, the relationship between these traces and performance requires systematic evaluation [1]. Third, organizational flexibility as measured through the fluidity of the social networks detectable from electronic trace data is difficult to ground both theoretically and empirically solely in analysis of those traces [34, 28, 29, 30]. Fourth, although features, like leadership and leadership changes, can easily be extracted from the social network of a VO, what organizational relationships should be mapped in the social network, and how, may vary significantly across domains and contexts, as shown in many field studies, such as [9, 25, 23, 31, 36, 3, 28, 29, 30]; correspondingly it is not obvious how each network relates to both structural fluidity and performance. Fifth, although the characteristics that we have identified above as contributing to a structural fluidity index can be – individually – relatively easily computed and analyzed, the extent to which each needs to be considered and its "weight" in such an integrated index is not necessarily self-evident; in fact, it may vary depending on the specificity of an individual organization or an organization domain, which calls for contextualization of the index-building procedure.

For all of those reasons new methodological approaches to VO research are required to address these challenges. We have started to address the challenges listed above with a method and ontology for the study of virtual organizations that, which we refer to as *"Group Informatics"* [28, 29, 30]. A principal tenet of Group Informatics is the focus on the small group as the unit of analysis in the field, in recognition of the central role that small groups play in organizational change [33, 35], societal change [19], and ICT use [53, 24]. Another tenet – as we have already mentioned – is the rooting of the analysis in the electronic traces of the interactions that are mediated by the computerized environment of the VO. However, an additional factor is the contextualization of traces with respect to the socio-technical properties of that environment, such as artifact types, members' characteristics, or interaction attributes and meta-data. The contextualization step is important in recognition of the fact that VOs are not a single, uniform construct, but include a set of organization types, which exhibit varying degrees of, for instance, virtuality, stability, and expected duration [11]. For example a VO like Wikipedia exhibits highly formalized structures and processes [6, 39], whereas the long tail of VOs typically lack that level of formality. Finally, Group Informatics seeks the integration of quantitative and qualitative methods of analysis, to allow for triangulation of findings and thus augment explanatory power. A thorough discussion of the Group Informatics approach and how it can shape the investigation of structural fluidity is offered further below, in Sect. 8.6.

8.3 Related Work

8.3.1 Structural Metrics for Virtual Organizations

To work toward closing gaps in our understanding of structural change in VOs over time, we synthesized the following four core measures of organizational change from the literature: (1) VO leadership (degree and betweenness centrality); (2) VO membership (who is participating); (3) VO subgroups (what groups ‘move together’); and (4) Changes in VO organization size and structure (network level statistics). To understand the fluidity of a VO, it is necessary to analyze changes in each of these factors over time, and to work toward a synthesis of these factors into an overall indicator of structural fluidity.

Leadership is an individual measure. Understanding how leadership evolves in a VO is a key pathway for understanding structural fluidity. This includes measurement of VO leadership, made through social network analysis (SNA) from two well-established and complementary perspectives. The first is degree centrality, which is a measure that identifies people in the center of the action by counting the connections people have with others. In directed network analysis, connections in and connections out are measured separately and referred to as “in degree” and “out degree” centrality. Central people are either the formal heads of an organization, or central players in the informal organization; people regarded by their peers as possessing attributes that lead them to be referred to a lot. The second way leadership is identified through SNA is through a statistic referred to as betweenness centrality [21]. There are a number of derivatives of this statistic that have been used in different contexts [8, 20], and this measure is incorporated as a component of a methodological approach designed to facilitate valid network analysis from electronic trace data [26].

Betweenness identifies people who sit between groups in a larger organizational context. In a software VO, these are the people who facilitate the integration of code from multiple software teams, or cross a range of topics in online discussions [3, 23, 43]. Betweenness centrality is also referred to as brokerage, indicating that a person is a mediator between two other groups or categories of people in a transaction.

There are two main measures of structural change at the organization level that are used in prior literature on distributed work. First, there are changes to the size and composition of the social connections within an organization [47–49]. Second, a number of studies of VOs in OSS examine social network constructs of core membership, periphery membership and overall network centralization ([14–16]; Kevin [13]). Prior work does not, however, examine these measures of organizational structure over time.

8.3.2 Measuring Change in an Organization Structure

Structural fluidity is conceptually similar to change detection in virtual networks. Change detection research focuses on identifying change in social networks composed either entirely of computational agents in the case of simulations or entirely of real people in the case of applied studies. This work contributes to our understanding of the differences in these types of networks and limitations of existing network analytic techniques for detecting change. McCulloh [44] defined a set of statistical control charts capable of detecting statistically significant changes in social networks. Control charts demonstrate validity in controlled, software agent networks, but have yet to be demonstrated as valid in the analysis of change in social networks involving actors in physical or virtual organizations composed of humans. The challenge with detecting change in human networks is that these networks change a lot; therefore, finding actionable, meaningful changes with computation alone becomes difficult.

To mitigate these challenges, McCulloh's [44] work, and the work of others examining longitudinal statistics for social network evolution are primarily focused on highly structured organizations like the military. In these types of organizations, comparisons across smaller social aggregations may provide immediate information about changes in leadership structure in a platoon. To build understanding of how smaller, decentralized social groups (with no obvious or formal leadership) interact through technology requires research methods that reflexively analyze and triangulate trace data with findings from content analysis, interviews and other qualitative methods [23].

Projects on GitHub provide a new, data rich site for examining organizational change where there is not an a priori structure like one finds in military organizations. VOs on GitHub are emergent virtual and decentralized organizations that generate electronic trace data reflecting a significant portion of the social, task and information behaviors of participants.

Other studies describe organizational practices qualitatively, or examine trace data computationally. For example, Geiger and Ribes [22] propose trace ethnography as one possible methodological approach, but, like Stahl's [53] extensive ethno-methodologically informed analysis of electronic trace data shows, the approach does not scale to large conversations or longitudinal studies of VOs.

In contrast, computational analysis of trace data is demonstrated to be effective for identifying clusters of interaction or keywords from large corpora of data [39]. The main critique of computationally focused analysis of trace data is that often it makes a limited account of social science theories and is not triangulated with data describing the underlying social phenomena. Livne, Simmons, Adar and Adamic [42], for example, contrast network and linguistic analysis of Twitter data during an election cycle in the US, showing the network model as nominally more predictive of the outcome than the language model. Both models, however, are built around a binary choice between two candidates, and were only nominally more predictive than simple selection of an incumbent (88 % for the network model vs. 81 % for the incumbent status model). These and other computational social science studies that do not fully incorporate social science theory in their framing [12, 56] make a more limited contribution to our understanding of how behavioral data about people can be used to describe organizational change.

To measure structural fluidity, some combination of methods from social science [22, 26, 38, 53], prior studies in a particular context [14] and computational methods (Goggins, Valetto, Mascaro, & Blincoe, Published Online First; [46]) are required. An integrated approach will overcome known issues of validity and theoretical coherence associated with the computational analysis of electronic trace data [34].

8.3.3 Measuring the Performance of a Virtual Organization

Measuring performance is contextual, since performance is necessarily defined in a domain-specific way. Consequently, it is hardly possible to come up with generalizations that can be applied to Virtual Organizations within diverse domains. However, having ways to measure performance is of course a paramount concern for those VOs that structure themselves and operate as communities of practice [60], or – according to [5] – network of practices.

We review hereby domain-specific performance indicators in Software Engineering, Online Learning, Disaster Relief and Social Media, which are among the most often studied fields where VOs are deployed and operate. Those are also the fields in which our own interest lies, in terms of experimental and fieldwork aimed at establishing, understanding and structural fluidity assessment vis-à-vis VO performance.

8.4 Software Engineering

Concepts of performance in a software development organization are generally tied to either the quality of the product, or the effectiveness of the process. For our purposes, many product-derived performance metrics are scarcely actionable, as they become available *post hoc*, or at least out of band. For example, the number of residual defects is a major quality factor for a software release, but it is only known after exhaustive in-house testing, or following post-release customer feedback; that is the reason why software engineering research has spent a lot of effort on predictive models that attempt to proxy and anticipate the actual defects, their count, or their density within specific modules of the software product [2, 63]. Other often-used indicators that are used for instance in a prominent VO model like Open Source Software (OSS) projects include adoption [51], or maturity [18, 61] of the software product. The extraction of metrics for all of these indicators typically requires a long observation period.

Metrics that predicate upon the effectiveness of the software process encompass aspects like the organizational health or efficiency. Health metrics are, again, used extensively to analyze OSS. They try to conceptualize the performance of an open source community as its ability to thrive and attract a continued influx of contributions (and contributors), and focus on the numbers of participant in the VO in different recognizable roles ad their trends over time [18], or look at characteristics and patterns within the social network of the VO [13, 15, 62]. Efficiency metrics look at the issue of productivity by evaluating the ability of the VO members to fulfill project tasks quickly and correctly. They originate from a modality of work organization and assignment that has become prevalent in large and distributed software development organizations, in which the atomic units of work are *Change Request* (CRs), which are posted in a public, computer-mediated place (among the most popular tools implementing those CR repositories there are Bugzilla, Jira and GitHub) either by members of the project or external actors (for example, end users of the software). CRs are collectively triaged by the VO for relevance and priority, and then assigned to specific VO members, or self-assigned. The literature – see for instance [9, 45, 65, 64] – proposes a variety of efficiency indicators that can be derived from the timeline and workflow of the CRs that enter the system, including the rate of CR resolution over time; the turnaround time of CRs; the number of CRs that remain open or unassigned; the rate at which code is contributed to resolve open CRs; or the number of such code contributions that get accepted and incorporated in the project code base vs. the number of contribution that do not pass quality assurance and are rejected.

8.5 Disaster Relief

Disaster response is a different specific context than software engineering, but has analogous concerns with performance, process and coordination behavior. Measurement of performance in the use of Internet during a disaster is not yet prevalent, but the research to date, including our own [28], demonstrates that information quality and the presence of coordination behavior are two important factors that contribute to the usefulness of these media during a crisis. This extends Palen et al.'s [50] vision for the future of disaster management, which leverages the use of ICTs by focusing on the potential of members of the public during disaster situations. They suggest that supporting the public and enhancing their ability to make good, timely decisions can reframe disaster relief as a socially distributed information system [50].

Bui et al. [7] developed a framework for conceptualizing the types of issues that emergency relief workers must overcome, suggesting that the central issues in disaster relief management are information, coordination and the effects of disaster relief work on workers [7]. Information issues include information distortion and inconsistencies that must be reconciled. Coordination among governments and NGOs can be problematic due to government reluctance in releasing information with potential security implications and communication incompatibilities, including both language and technology [7].

Measurement of performance in the use of Internet during a disaster is not yet prevalent. However, research to date, including a framework developed by Bui et al. [7] as well as our own investigations [28, 29, 30], reveal that information quality and the presence of coordination behavior act as important factors that contribute to the usefulness of these media during a crisis. Information quality issues include distortions and inconsistencies that must be reconciled, and lack of effective coordination behaviors among governments and NGOs can present problems due to communication incompatibilities, including both language and technology [7], and governmental reluctance to release information with potential security implications. These identified factors extend Palen et al.'s [50] vision for the future of disaster management, which leverages the use of ICTs by focusing on the potential of members of the public during disaster situations. They suggest that supporting the public and enhancing their ability to make good, timely decisions can reframe disaster relief as a socially distributed information system [50].

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8.6 Methodology

One component of our work to date is the development of a methodology and ontology for conducting research involving electronic trace data. Performance and structural fluidity are our specific concerns in this chapter. To address these questions the more general problem of ensuring a connection between existing theory, research questions and the structure and meaning of electronic trace data is important for ensuring the validity of research [34]. Group Informatics proposes a systematic approach to ensuring a deliberate connection between trace data, theory and research questions. Connecting requires reflexivity between the human review of how individuals, teams and organizations are functioning and computational approaches to the trace data they leave behind in the technologies.

8.6.1 Overview of the Group Informatics Method

With Group Informatics, we have developed a comprehensive methodological approach and ontology for the study of virtual organizations [28, 29, 30]. The concept of interaction is central to Group Informatics, but we are interested in the contextualizing of member interactions, by operationalizing Dourish's view of context as a dynamic construct [17]. Therefore, our approach calls for the

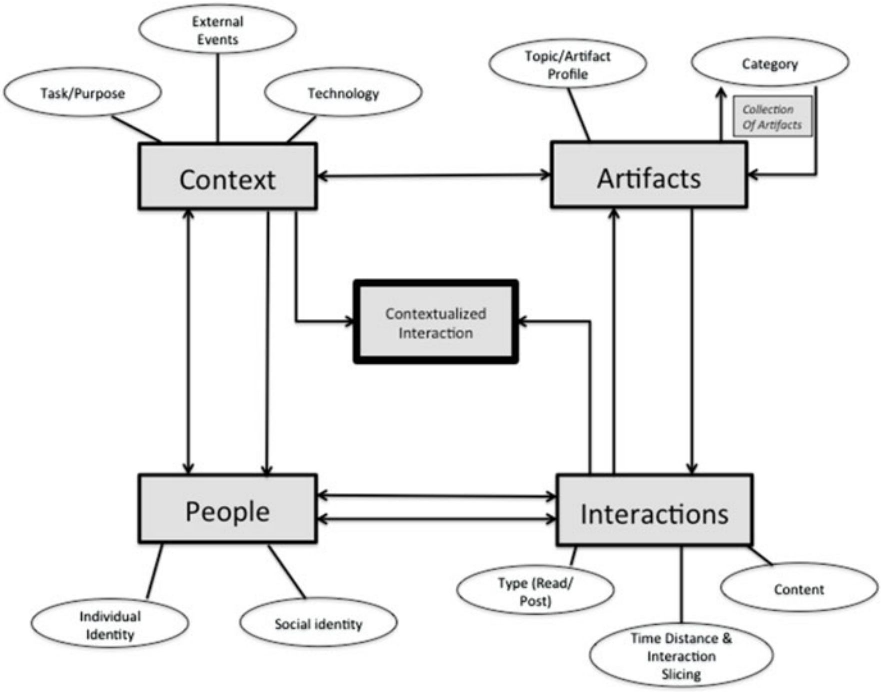

Fig. 8.1 Model overview of group informatics

contextualization, aggregation and weighting of member interactions, according to an ontological model that comprises four core components: (a) artifacts, (b) interactions, (c) context, and (d) people. Each of those components has dimensions and relationships with the other components.

The four components in Fig. 8.1 contribute to into a network of contextualized interactions, which are weighted and can be decorated with additional attributes (meta-data), and which are bound to vary over time. Contextualized interactions may be either interactions between members, or interaction of members with artifacts, in which case artifacts are regarded as boundary objects around which interactions occur [54, 41]. The network of contextualized interactions represents social phenomena within the VO, and we can ask research questions of them and investigate them by means of network analysis methods; in [26, 27], we exemplify the analysis approach enabled by the Group Informatics model, and show how it applies to the question of identifying emergent and informal groups within larger VOs in two diverse cases from the software engineering and online learning domains.

Figure 8.2 conceptualizes how interactions are aggregated and weighted. The aggregations and weights are not computational choices; they are choices based on developing a qualitative, grounded understanding of how people are interacting with

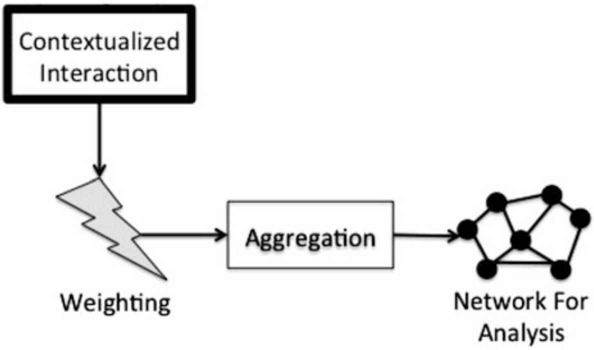

Fig. 8.2 Model for context adaptivity derived from electronic trace data of interactions

each other in the system that generates trace data. Such an understanding emerges from interviews, surveys, and systematic, ethnographic observations of online teams and organizations, as described in Goggins et al. [26, 27].

8.6.2 Conceptualizing and Measuring Structural Fluidity

Structural fluidity is a measure of organizational change. As the dynamics of a VO are self-organized (or at least originated from a mix of directed and self-organized changes), we want to leverage the methodological approach of Group Informatics and its contextualized networks to first measure multiple facets of structural fluidity, and then compose them in a single statistical index.

Some motivations for having a structural fluidity index are: to assess analytically that an organization is evolving; to what extent (how much) it is evolving; and what the trend of this evolution is over time. Our ultimate goal, however, goes beyond observation, and aims to answer the following research question: **to what extent does structural fluidity correspond with performance in VOs?** For that, we want to associate this measure of organizational change to measures of performance across different kinds of VOs.

To attack the problem, we use contextualized networks and apply on them network-analytical metrics like degree centrality. Network statistics capture primary facets of an organization structure and its dynamism; among them, measures of leadership, membership volatility, the size, group count and participation trajectory of the VO. The extent of movement of members between and within qualitatively and quantitatively identified groups, which are sometimes referred to as neighborhoods in Social Network Analysis. Representing the structural dynamism of virtual organizations is then connected to studies seeking to understand how contributors and leaders measure performance.

8.7 An Example from Software Engineering on GitHub

Using prior studies of OSS and organizations, we proposed and evaluated a set of factors to measure the structural fluidity of VOs, and operationalized those factors in a case study of one GitHub project. We identified the *type of work performed* as a potential covariant for understanding structural fluidity in virtual software organizations more comprehensively. The role of the type of work warrants ongoing study.

We demonstrate that the rails/rails project on GitHub has dynamic, distributed leadership; fluid membership; non-static subgroups, both measured from an individual viewpoint (ego networks) and at the VO aggregate level; and variations in the rate of new participation. Together, these factors suggest a type of structural fluidity in the rails/rails organization that is not previously operationalized in open source software development or organization studies. Our fine-grained analysis of contribution type illustrates that individuals take on different work during different time periods.

Our findings lead us to consider three specific areas for continued empirical study of virtual organizations and the development of VO theory. First, our observations offer a starting point for the development of an index of VO structural fluidity, conducive to comparative studies of VOs. Second, we suggest considering how VOs that demonstrate a high degree of structural fluidity may be thought of more like "*impromptu* collaborations" than traditional organizations. Third, we argue that, unlike non-virtual organizations that employ traditional knowledge from management to effectively scale up, VOs present an opportunity for scalable, innovative organizations to embrace an approach more influenced by values of anarchy than hierarchy.

8.8 Quantifying Structural Fluidity

The design of collaborative computing systems is a recognized wicked problem [22]. Understanding the uptake and use of context specific technologies and practices is similarly challenging. Working toward the development of techniques that can offer a comprehensive, comparative measure of VO change is therefore useful for designers and VO stakeholders.

The feasibility and importance of developing a synthetic index of structural fluidity emerges from our findings. We proposed a set of factors that can signify structural fluidity and that are associated with quantitative measures that can be observed directly from qualitative analysis of trace data. Some of those factors are "macro", i.e., regard the organization as a whole: these include the total number of participants (network size), the number of newcomers, and changes in subgroup composition. Other factors are "micro", i.e., regard individual VO actors, and characteristics of the corresponding network position: these include measures of degree and betweenness centrality, and measures of dissimilarity of the ego network of an actor. Both macro- and micro- measures can be observed repeatedly over time, so that it is possible to construct a set of time series (one for each of the factors considered).

In a socio-technical system like a VO, it is unlikely that the values obtained from those repeated observations are independent. One way to conceptualize fluidity is that – although an observation of a factor at any given time is not independent from the accumulated history of the subject (either an actor in the organization, or the organization at large) – the time series of the observations taken as a whole should not show significant patterns, including stability, trends or periodicity. Rather, the more fluid the structure of the organization, the more random the time series should look. Our Ljung-Box tests illustrate the type of randomness expected.

This is consistent with the idea that in a highly fluid VO collaborations are *impromptu*, and past collaborations may not repeat in the future, and do not necessarily dictate how future collaborations shape up. We hypothesize that routine organizational change is a premise for many VOs. Measuring that change and drawing comparisons then becomes essential. One method to assess whether the VO being studied shows fluidity is the use of statistical tests of randomness for the corresponding time series. For instance, the Ljung–Box test can be used to refute the null hypothesis of randomness; its Q statistics measures, so to speak, the "lack of randomness" of a time series, with higher Q values (when coupled with significant p levels) meaning that the time series is further away from randomness. In our terms, though, high Q values signify a lack structural fluidity. We do indeed observe such low structural fluidity among a small set of contributors in sustained leadership and coordination positions. However, most of the organization is highly fluid.

By assessing the randomness (or lack thereof) of the time series for each of the factors we have proposed and explored in this paper, we quantify how much a VO is structurally fluid "according" to that factor. This creates a multi-dimensional criterion for assessing the fluidity of VOs.

Moving from these multiple dimensions towards a unified indicator of the structural fluidity of organizations will require further work to discern which factors provide the most reliable and valid indicators of structural fluidity. We should also investigate what relationships may exist between the various factors, and their measures. There is ample space for further research in this area; for instance, our observations of differences and variability of type of work in GitHub, once fully developed, could become a key for validating the explanatory power of each factor, and the relationships between those factors. We regard our current work as a starting point for examining structural fluidity in individual VOs, and for comparing VOs.

8.9 Impromptu Collaborations: A Path to Theories of Structural Fluidity

Rails/rails has nominal central control in the "merger" role, but a growing number of contributors emerging through GitHub's pull request process. These widespread, diverse collaborations are much more spontaneous, ad hoc, and at times short-lived than traditional organization forms or bureaucratic organization forms like those found in Wikipedia. We suggest that it is possible that GitHub appears to support an organizational model that is neither hierarchical nor tribal in its form.

Rails/rails exhibits a small set of people in hierarchical leadership roles – called mergers – who do the work of building and distributing code (the product). Beyond contributors in those narrow roles, leadership is highly fluid. We do not observe hierarchy; and the volume of productive work makes managed anarchy seem implausible, yet not wholly inconsistent with what our data illustrates. The development of better VO theories will, we think, result from examination of socio-technical environments like GitHub, and openness to a range of unconventional, post-organizational research questions. Structural fluidity, applied as an index across VOs, has a potential to demonstrate its value in this kind of research, in terms descriptive utility.

We present these findings recognizing important limitations and insights. With regards to limitations, the focus on a single VO in GitHub is not generalizable to other VOs, though our ongoing studies suggest rails/rails is similar to many GitHub VOs, just on a smaller scale. This is an exploratory, proof of concept examination of the idea of structural fluidity that lays groundwork for the development of reliable and valid measures of differences in VOs. We show evidence of structural fluidity and explain the role of different types of leadership across a number of indicators that lead us to propose an index to support the ongoing study and measurement of VOs.

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