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Research Statement

The following pages explain my past activities and future plans as an information science researcher interested how new uses of information and communications technologies (ICT) enable people to work together in new ways. The ways that people can work together depends in large measure on the availability and cost of communications and coordination. Today, ICT—electronic messaging, groupware, the Internet, machine learning—are radically changing the cost of communications and decision making, enabling novel forms of collaboration. Most striking are instance of cooperative work that rely on self-organized voluntary contributions: distributed teams of Free/Libre/Open Source Software (FLOSS) developers who produce reliable and popular software without working for a common organization; volunteer editors who create Wikipedia; and millions who contribute to scientific projects by contributing or analyzing data.

Because new forms of organizing is such a broad research area, my work has spanned a number of topics, but all with a connection to the central issue of ICT support for new modes of work. My research includes in-depth analyses of novel forms of work, development of theories that describe and explain the roles ICT do and can play in this kind of work, and development and evaluation of systems to support it. I adopt a perspective of organizing as recurrent patterns of communication. In this view, uses of ICT are enacted by individuals who, through their actions, change the conduct of their work in response to the capabilities of these technologies. Individual-level changes in work lead in turn to changes to work processes, which reflect the choice and sequencing of tasks to accomplish intended outcomes.

To conceptualize the linkage between the use of ICT and changes in processes, I consider in particular the how the use of ICT affects the relative cost of different coordination mechanisms. Coordination mechanisms are the topic of coordination theory (Malone & Crowston, 1990, 1994). The basic ideas behind coordination theory are simple. The main focus is on processes composed of activities that require and create resources. For example, in software bug fixing, a process I studied in my dissertation (Crowston, 1991), activities include determining that a bug exists, creating a patch for a bug and integrating the patch into the system. Resources include a description of the bug and software modules as well as the efforts of the programmers. The key notion in coordination theory is dependency, created by the interplay between activities and resources, and requiring additional work to manage. For example, only someone with specialized skills can create a patch, so additional work is necessary to find an appropriate programmer (a task assignment problem). When multiple bugs need to be fixed in a single software module, additional work is necessary to ensure that the changes made do not conflict with each other (a shared resource problem). Since its initial presentation, coordination theory has been applied by a number of researchers in a variety of settings, as shown in a review (Crowston, Rubleske, & Howison, 2006).

An early study of the impact of ICT was set in the real estate industry, supported by two grants from the NSF (IIS Grant 97-32799, 1998–1999, $70,000; and IIS 00–00178, 2000–2002,

$269,969, both with Rolf Wigand and Steve Sawyer). Real estate was a particularly interesting industry to study because it is information-intensive and is experiencing IT-related change. We began this study to test predictions of disintermediation of real estate agents caused by Web access to property listings and other uses of ICT (Crowston, Sawyer, & Wigand, 2001; Crowston & Wigand, 1999; Myers & Crowston, 2004; Sawyer, Wigand, & Crowston, 2005).

We found that agents assemble a portfolio of technologies to support their work (Sawyer, Crowston, & Wigand, 2014). However, our analysis suggests that for US real estate agents, the level of strong ties to other professionals are more predictive of overall earnings than are weak ties to potential clients (Crowston, Sawyer, & Wigand, 2015) (this paper won the ASIS&T SIG-SI award for Best Published Social Informatics Paper of 2015). We interpret this result by noting that a real estate transaction is embedded in a sequence of other transactions (i.e., is part of a larger sales process) and that ICT affects some steps of these process (e.g., finding a listing) but not others (e.g., moving the transaction to the close). Strong ties from agents to other professionals are particularly valuable for the parts of the process that ICT has not affected.

Another early project was on the nature of document genres, defined as "a distinctive type of communicative action, characterized by a socially recognized communicative purpose and common aspects of form" (Orlikowski & Yates, 1994, p. 543). My interest in document genre was originally sparked by my efforts to model organizational communications in terms of different message types. Genres are interesting because they are social constructions that embody a community's communicative practices and are thus an important element of an information system taken in the broadest sense. As technology enables new forms of communication, the set of genres in use evolves, providing insight into how users are adopting and adapting to technology.

Marie Williams and I published two conference papers and one journal article on digital genres. In the first paper (Crowston & Williams, 1997), we examined a sample of Web pages to determine what genres are currently in use and to see if new genres were beginning to emerge on the Web. An extended version of this paper was published as a journal article (Crowston & Williams, 2000). In the second paper (Crowston & Williams, 1999), we examined a particularly common genre on the early Internet, the Frequently Asked Questions document, or FAQ, to demonstrate how the ability to link pages on the Web changed this genre.

Barbara Kwasnik and I had an NSF-supported project (NSF IIS Grant 04–14482, 2004–2006, $302,685) exploring how exploitation of the dual nature of genres, purpose and form, might be used to improve information access systems, such as web search engines. The grant supported construction of a corpus of web pages labelled by genre (Kwaśnik, Chun, Crowston, D'Ignazio, & Rubleske, 2006; Rubleske, Crowston, Kwasnik, & Chun, 2007), which we used as the basis for a mockup of a genre-enabled web search engine. While initial experiments were promising, unfortunately the results did not hold up in a broader test. However, my interest in genre has informed later studies, for example, a study of document use in FLOSS teams (Østerlund & Crowston, in press).

In recent years, my research has examined a number of different kinds of novel forms of organizing that have emerged with the extensive use of ICT. All are forms of virtual organizations, those that appear to the outside world to be a single organization but where the work is done by multiple cooperating organizations (or individuals). Some of these are formal organizations. For example, one paper (Katzy & Crowston, 2008) discusses an action research study of a virtual organization (the "Virtual Factory") in the precision machining industry in Germany. This paper presents a model of how the competencies of multiple companies can be "rallied" into a coordinated effort. A second paper presents a case study of a system development project in a different virtual organization, *ARC Transistance*, the alliance of European automobile clubs (Katzy, Sung, & Crowston, 2016).

Other work has unpacked the word "virtual" to provide a more precise meaning for this over-used term. Mary-Beth Watson-Manheim, Kathy Chudoba and I published a paper (2002) that suggested that one way to think about virtual work is a work characterized by numerous discontinuities: a lack of coherence in some aspects of the work setting (e.g., organizational membership, business function, task, language or culture). A second paper analyzes how discontinuities are perceived by workers in virtual settings (Watson-Manheim, Chudoba, & Crowston, 2012). We have since applied the framework to analyze the types and frequency of meetings (Chudoba, Watson-Manheim, Crowston, & Lee, 2011) and to scientific research projects (Crowston, Specht, Hoover, Chudoba, & Watson-Manheim, 2015).

A particularly prominent example of virtual organizations enabled by the use of ICT can be found in the blossoming of Free/Libre/Open Source Software[1] (FLOSS, e.g., Linux or Apache). Key to our interest is the fact that most FLOSS software is developed by dynamic self-organizing distributed teams comprising professionals, users (von Hippel, 2001; von Hippel & von Krogh, 2002, 2003) and other volunteers working in loosely-coupled teams. These teams are close to pure virtual teams in that developers contribute from around the world, coordinate their activity primarily by means of computer-mediated communications and meet face-to-face infrequently if at all (Raymond, 1998; Wayner, 2000) (though our research showed that these rare face-to-face meetings are useful (Crowston, Howison, Masango, & Eseryel, 2007)). While these features place FLOSS teams towards the end of the continuum of virtual work arrangements, the emphasis on distributed work makes them useful as a research setting for isolating the implications of this innovative way of working together.

My studies of FLOSS project teams were supported by a series of grants from the NSF (NSF IIS SGER Grant 03–41475, 2003–2004, $12,052; NSF IIS Grant 04–14468, 2004–2006,

1 The free software movement and the open source movement are distinct and have different philosophies but mostly common practices. The licenses they use allow users to obtain and distribute the software's original source code, to redistribute the software, and to publish modified versions as source code and in executable form. While the open source movement views these freedoms pragmatically (as a development methodology), the Free Software movement regards them as human rights, a meaning captured by the French/Spanish word 'libre' and by the saying "think of free speech, not free beer". (See http://www.gnu.org/philosophy/ and http://opensource.org for more details.) My research focuses on the development practices of these teams, which are largely shared across both movements. However, in recognition of these two communities, I use the acronym FLOSS, standing for Free/Libre and Open Source Software, rather than the more common OSS.

$327,026; NSF HSD Grant 05–27457, 2005–2008, $684,882). My first paper in this area, written with Barbara Scozzi, analyzed FLOSS teams using the framework developed for the Virtual Factory (Crowston & Scozzi, 2002). Subsequent papers have presented a research model for studying FLOSS team practices (Crowston, Annabi, Howison, & Masango, 2005) and examined various components of this model, including the nature of success for FLOSS teams (Crowston, Howison, & Annabi, 2006), team social structure (Crowston & Howison, 2005, 2006; Crowston, Li, Wei, Eseryel, & Howison, 2007), communication patterns (Crowston & Shamshurin, 2017; Wei, Crowston, Eseryel, & Heckman, 2016), leadership (Crowston, Heckman, Annabi, & Masango, 2005), and coordination of bug fixing (Crowston & Scozzi, 2008) and development processes (Howison & Crowston, 2014). An extension of this work examined the stages of engagement with a volunteer project, drawing on data from a survey of Wikipedia editors (Crowston & Fagnot, 2018).

Academic interest in FLOSS development has increased substantially as I was studying it, and I was able to play a role in shaping the development of this research area through participation in some of the early conferences. Examples of recognition of this status was an invitation to give a keynote address for conference on *Empirical Assessment of Software Engineering* and to contribute a position paper for a special issue of the journal *First Monday* on Open Source Software (Crowston, 2005). Our group wrote one of the first review articles on the topic (Crowston, Wei, Howison, & Wiggins, 2012).

I have also sponsored the development of shared resources for the community through the FLOSSMole project (http://ossmole. sourceforge.net/), a repository for data on FLOSS teams (Conklin, Howison, & Crowston, 2005; Crowston & Squire, 2017; Howison, Conklin, & Crowston, 2006), itself NSF-supported (NSF CRI Grant 07–08437, 2007–2010, $100,000). This interest in shared data led to a number of side projects, e.g., work on best practices for data management (Qin, Crowston, & Kirkland, 2017), on systems for data sharing (Crowston, 2015) and on motives data reuse (Curty, Crowston, Specht, Grant, & Walton, 2017). A particular focus has been recommendations for how to analyze trace data, meaning data that are collected as a side effect of engagement with an information system (Crowston, 2017; Howison, Wiggins, & Crowston, 2011; Østerlund, Crowston, & Jackson, In press).

The work on genre and FLOSS spun off a current project on supporting stigmergic coordination, meaning coordination that happens through the work itself rather than through explicit communication. The project started with observation that FLOSS developers seem to rely on the shared code they are developing to provide guidance for their work (Bolici, Howison, & Crowston, 2016). Stigmergy also seems to occur to some extent in Wikipedia, another project with a shared work product (Rezgui & Crowston, 2018). I have a current NSF-supported project (IIS Grant 16–18444, 2016-2019, $499,931) in which we are developing and evaluating a cooperative work system to support stigmergic coordination for data science teams. The work is in its early stages, but has yielded one conference paper so far (Saltz, Heckman, Crowston, You, & Hegde, 2019) with more in the works.

My recent research has examined another form of virtual organizing, namely citizen science, that is, scientific projects that rely on participation from members of the general public, e.g., contributions of data or analysis of data. This work has been supported by a series of NSF grants. The first grant (OCI Grant 09–43049, 2009–2011, $150,000) supported studies developed a model for understanding the factors involved in a citizen science project (Newman et al., 2012; Prestopnik & Crowston, 2012a; Wiggins & Crowston, 2010, 2012, 2015).

A second grant (SOCS Grant 09–68470, 2010–2013, $478,858) supported work on a citizen-science project that incorporated aspect of games to motivate contributions (Prestopnik & Crowston, 2012b; Prestopnik, Crowston, & Wang, 2014, 2017). A third grant (SOCS Grant 12–11071, 2012–2015, $305,099) started an ongoing collaboration with the Zooniverse project. This grant supported a number of improvements to the Zooniverse platform and studies of volunteer behaviour (Crowston, Jackson, Østerlund, & Mugar, 2016; Jackson, Crowston, & Østerlund, 2018; Lee, Crowston, Harandi, Østerlund, & Miller, 2018; Mugar, Østerlund, Jackson, & Crowston, 2015).

A final grant (INSPIRE Grant 15–47880, 2015–2018, $999,663) supported development of the Gravity Spy system (Zevin et al., 2017), which incorporates an initial machine-learning (ML) supported classification of images. However, rather than replacing the human classifications, the ML results are used to pick images that should be easy for the volunteers to classify and thus support their learning to do the task. Another innovation of this system is that it asks advanced volunteers to develop their own classification, rather than simply applying those of the science team (Crowston, Østerlund, & Lee, 2017; Jackson, Crowston, Østerlund, & Harandi, 2018).

The Gravity Spy project's mix of human and machine classification has sparked an interest in understanding how work will evolve given the enhanced capabilities of ICT, specifically artificial intelligence and machine learning. With Jeffery Nickerson and Ingrid Erickson, I am the PI of an NSF-supported Research Coordination Network on Work in the Age of Intelligent Machine (IIS Grant 17–45463, 2018–2023, $499,796, https://waim.network/) that seeks to bring together researchers interested in this topic through workshops, conferences and cyber-infrastructure. My own research on this topic is still developing and so far has led to one conference paper proposing a typology of machine-learning support for work (Crowston & Bolici, 2019).

In summary, my work has spanned a number of topics, but always with a connection to the central theme of coordination and new forms of work. My research output taken as a whole makes an important contribution to the theory and practice of advanced systems development and technology-based work design.

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