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Spatio-temporal filtering techniques for the detection of disaster-related communication

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ABSTRACT

Individuals predominantly exchange information with one another through informal, interpersonal channels. During disasters and other disrupted settings, information spread through informal channels regularly outpaces official information provided by public officials and the press. Social scientists have long examined this kind of informal communication in the rumoring literature, but studying rumoring in disrupted settings has posed numerous methodological challenges. Measuring features of informal communication —timing, content, location—with any degree of precision has historically been extremely challenging in small studies and infeasible at large scales. We address this challenge by using online, informal communication from a popular microblogging website and for which we have precise spatial and temporal metadata. While the online environment provides a new means for observing rumoring, the abundance of data poses challenges for parsing hazard-related rumoring from countless other topics in numerous streams of communication. Rumoring about disaster events is typically temporally and spatially constrained to places where that event is salient. Accordingly, we use spatio and temporal subsampling to increase the resolution of our detection techniques. By filtering out data from known sources of error (per rumor theories), we greatly enhance the signal of disaster-related rumoring activity. We use these spatio-temporal filtering techniques to detect rumoring during a variety of disaster events, from high-casualty events in major population centers to minimally destructive events in remote areas. We consistently find three phases of response: anticipatory excitation where warnings and alerts are issued ahead of an event, primary excitation in and around the impacted area, and secondary excitation which frequently brings a convergence of attention from distant locales onto locations impacted by the event. Our results demonstrate the promise of spatio-temporal filtering techniques for "tuning" measurement of hazard-related rumoring to enable observation of rumoring at scales that have long been infeasible.

The increasing prevalence and accessibility of online data heralds a new regime for data collection and analysis. We enjoy greater access to large-scale, observational social science data, much of which has a textual component. This new data regime

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brings great opportunities but also poses several challenges (Boyd and Crawford, 2012: King, 2011). While many new data sources offer opportunities to analyze and understand social phenomena with precision and at scales that have long been infeasible, the scope of such data can be overwhelming. These kinds of large-scale data are often too large to examine manually and are frequently noisy due to a conglomeration of different competing signals of social processes. This challenge creates an opportunity for the development of filtering techniques to refine signal from noise in order to highlight a particular activity or set of activities.

Scholars from a variety of fields have recently turned attention towards identifying signals of social processes in large-scale, user-generated online text data from platforms such as Twitter and Facebook. At any given moment individuals use online platforms to discuss a wide variety of topics such as news, sports, work/school, weather, and what they ate for lunch. Each of these topics has its own "signal" of user activity (reflecting the text and information generated by users) and the site's collective activity is awash with signals from a nearly endless array of topics. Identifying particular signals of user behavior, such as discussing specific topics or frequenting specific locations, is an ongoing challenge that is complicated by the bevy of signals of other activity. The challenge of parsing large volumes of online text to identify signal has drawn much attention in recent years (Ferrari et al., 2011; Hollenstein and Purves, 2013; Mamei et al., 2010; Pozdnoukhov and Kaiser, 2011). While the application in the online environment is novel, the general problem is not. Interest in automated signal processing in noisy environments (Fawcett and Provost, 1999; Hamid et al., 2005; Macleod and Congalton, 1998; Ribeiro et al., 2012; Singh, 1989; Stauffer and Grimson, 2000) predates the proliferation of user-generated online activity, and we can apply the lessons learned in those contexts to the online context.

Although the signal identification problem is not new, detecting signal in the online environment poses new challenges that require novel solutions. Short message length and esoteric language and grammar in media like text messages and Twitter enhance the difficulty of identifying signals of social processes (Davis et al., 2011; Go et al., 2009; Kireyev et al., 2009; Kouloumpis et al., 2011; Pak and Paroubek, 2010; Yang et al., 2014). The challenges of detecting signals of social phenomena in the online environment implore us to develop a fundamental understanding of the social phenomena we intend to detect. Failure to understand the social processes underlying activity observed at large scale is dangerous and may lead to misleading or spurious results (Back et al., 2011; Boyd and Crawford, 2012; Johnson, 2014; Lazer et al., 2014; Leinweber, 2007), such as misclassifying failure-to-connect error messages as "anger" messages in a stream of pager messages or overestimating flu incidence based on search term activity on Google. To prevent such outcomes we harness what is known about the social phenomenon—in this case, rumoring behavior in the context of disaster events—in order to filter activity selectively as we search for signal of hazard-related rumoring.

This principle of systematic filtering motivates the techniques we develop in this paper. Here our primary goal is to develop an approach for measuring signal of human activity that varies markedly across time and space. Understanding the basic principles of a phenomenon of interest is key to developing effective strategies for measuring that phenomenon. We introduce a spatio-temporal filtering approach for measuring signal and demonstrate its utility by illustrating an example of detecting signal of disaster-related rumoring activity. Using what is known about social responses to disaster events (impending or realized), we selectively filter timestamped streams of geolocated, informal communication activity by time and location in order to identify surges of rumoring activity in response to a disaster. Spatio-temporal filtering enhances our ability to detect events by utilizing the signal produced by sources that are known (or expected) to produce reliable information, thereby enhancing our ability to detect distinct activity patterns above and beyond typical global signal (i.e. background noise representing the array of signals irrelevant to our focus). We proceed from here by characterizing rumoring in disaster contexts, reviewing techniques for event detection, and illustrating strategies for how we can filter our data across time and space to identify local surges of disaster-related rumoring activity. We then describe various approaches one can take for filtering data and illustrate our technique with online, informal communication in the context of several different types of disaster events.

1. Informal response to disasters

The disruption of social structures and routines is a characteristic feature of disasters. Kreps (1984) defines a disaster as an event inducing damages, losses, and/or disruption, where the impact affects social structures and/or societies. Key to this definition is that a disaster compels a response from social units, often in response to the disruption of essential functions of society (Fritz, 1961). This response translates into action from individuals, households, organizations, and other social units (Drabek and McEntire, 2003; Drabek et al., 1981; Hughes and Palen, 2009; Leik et al., 1981; Sutton, 2010), often in the form of emergent and frequently novel behavior. While most disasters have some element of emergency response activity by formal organizations (e.g., search and rescue, firefighting, aid provision, triage), informal actors such as individuals and families engage in a variety of activities. They take protective action, verify official information (e.g., emergency alerts), supplement official information with information from friends, family, and neighbors, check the status of others, and engage in mitigation activities such as search and rescue, evacuation, and cleanup (Drabek et al., 1981; Hughes and Palen, 2009; Leik et al., 1981; Quarantelli, 1954, 1980; Sutton et al., 2013a,b). Citizen response routinely serves as the first emergency response during disasters, followed shortly thereafter by official emergency responders (Kreps, 1983). Informal response to emergency situations is a critical aspect of the hazard environment.

Informal communication is an essential component of disaster response. Informal communication includes, for example, face-to-face conversations between neighbors, phone conversations between friends, and emails exchanged among students.

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