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Core-periphery or decentralized? Topological shifts of specialized information on Twitter

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ABSTRACT

In this paper we investigate shifts in Twitter network topology resulting from the type of information being shared. We identified communities matching areas of agricultural expertise and measured the core-periphery centralization of network formations resulting from users sharing generic versus specialized information. We found that centralization increases when specialized information is shared and that the network adopts decentralized formations as conversations become more generic. The results are consistent with classical diffusion models positing that specialized information comes with greater centralization, but they also show that users favor decentralized formations, which can foster community cohesion, when spreading specialized information is secondary.

Introduction

In this paper we investigate how Twitter networks can shift from a centralized topology, characterized by a high core-periphery profile, to a decentralized topology characterized by low core-periphery estimates. Classical diffusion models (Rogers, 2010; Schon, 1971) posit that centralized networks are more efficient in spreading specialized information to specific communities of interest. On the other, recent studies have foregrounded the role of decentralized networks in disseminating behavior and facilitating the development of social norms that reinforce learning in local networks (Centola, 2010; Centola and Baronchelli, 2015). Centralized networks are particularly salient in sectors relying on a small number of specialists who engage a highly diverse and continuously expanding body of potential stakeholders, a diffusion system in which experts constitute the network core feeding information to the peripheral audience. Decentralized systems, on the other hand, facilitate the emergence of new ideas growing out of practical experience. Such systems lack a clear core or periphery as the information is more widely sourced and shared by all members of the network.

Twitter is an atypical social network in which the topological characteristics of both centralized and decentralized diffusion systems are present (Gabielkov et al., 2014; Kwak et al., 2010). The basic proposition of this study is that communities of interest assume different network formations that optimize the information diffusion from an active core to a relatively passive periphery; or inversely, allow the horizontal sharing of information that can be tailored to fit with users' needs where individual decisions on which source to seek information from are relatively free, thus facilitating adaptation and implementation by local users. We explore this proposition by isolating subsets of generic and specialized tweets posted by several communities of users involved in agriculture and subsequently measuring the core-periphery profile of their multiple, comparable subgraphs. For the purposes of this study, we refer to subgraphs as a defined set of nodes and arcs of the original Twitter graph selected on the basis of specific characteristics of the message.

Agriculture and the more specialized field of sustainable agriculture are an important and useful setting in which to study the diffusion of specialized information. Modern agricultural systems are experiencing a revolution in how knowledge is disseminated and exchanged among networks of outreach professionals, farmers,

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consumers, and community stakeholders. The traditional approach to agricultural extension is highly centralized and relies on a top-down, continuum model going from university researchers to cooperative extension agents and finally to farmers (Rogers, 2010; Van den Ban and Hawkins, 1996). With internet penetration rates growing in rural communities (USDA, 2015), stakeholders are increasingly adopting social media and other online forms of communication to share agricultural information across local, national, and global networks. Notwithstanding these major developments, the impact of network technologies to the diffusion of specialized information remains relatively uncharted, with only a handful studies exploring the use of social media within the agriculture and food sectors (Chowdhury et al., 2013; Rhoades and Aue, 2010).

Although agricultural extension services in the United States are historically associated with centralization (Rogers, 2010), sustainable agriculture comprises a subset of agricultural extension that can benefit from decentralized diffusion systems, with stakeholders increasingly adopting digital strategies to complement more traditional outreach systems (Lubell et al., 2014). Agricultural extension and outreach remains rooted in specialized information about agricultural practices, economic conditions, and other relevant decision-making parameters. This specialized information must be applicable at the local level to individual farms and agricultural communities, but more general ideas need to be developed at the global level by upscaling multiple local experiences and then downscaling information to catalyze local learning. Thus, the diffusion of specialized information about sustainable agriculture requires a capacity to continuously facilitate a recursive flow of local and global information, a dynamic that can benefit from both centralized and decentralized diffusion systems (Valente and Rogers, 1995).

As a consequence of this duality in communicating specialized agricultural information, the different strategies surrounding agricultural extension and sustainable agriculture outreach offer an ideal case study to investigate the diffusion of specialized information on social media. Sustainable agriculture is a quintessential example of a community where knowledge networks must spread information across specialized sub-communities that are concerned with different aspects of the complex global food system (Klerkx et al., 2015; Klerkx and Proctor, 2013). The overall knowledge network not only has to deal with internal components of the system, for example understanding climate change and water management, but must also link the specialized system to the broader global culture represented by social media platforms like Twitter. Sustainable agriculture is not unique in this way-we expect similar dynamics may apply to other broad epistemic communities, e.g. social media users discussing "energy independence," "national defense," and other similarly specialized topics (Lubell et al., 2011; Lubell et al., 2014).

However, sustainable agriculture is a particularly useful domain in which to study the dynamics between network structure and knowledge specialization because there is an important tradition of knowledge extension among the education and outreach professionals involved with agriculture (Clark et al., 2016). The traditional approach to knowledge extension was to deliver research findings from universities to farmers and other interested stakeholders via personal communication and networks of local extension agents. With the advent of new information and communication technology (ICT) and social media, extension professionals involved with agricultural knowledge systems (Hermans et al., 2015) are increasingly experimenting with online forms of communication and continue to contend with general ideas such as network centralization and knowledge specialization that may apply to the specific topics of interest for agriculture.

In the following, we briefly review the literature on diffusion of innovations and detail an approach to core-periphery analysis that returns a continuous measurement of the centralization observed in the network. In the later sections of the paper we present the results of this study and discuss the more general policy implications of our findings.

Specialization and network centralization

Classical diffusion models posit that innovation originates from expert sources and then diffuses uniformly to potential adopters who either accept or reject the innovation. The source of information is situated at the center of the communication network and adoption is mostly a passive act of imitation of the source behavior. This classical model was successfully applied to agricultural extension services and the underlying model is derived from Ryan and Gross (1943) seminal study that tracked the diffusion of hybrid corn throughout the Midwest. The original study identified diffusion agencies, commercial channels, and neighbors as key actors that informed farmers of the new seed and affected their rate of adoption. Much agricultural diffusion in the United States emerged from this centralized model, in that key decisions about how to diffuse them, and to whom, were left to a small number of technical experts (Rogers, 2010).

Schon (1971) called into question this seminal model by exploring the reality of emerging diffusion systems and criticizing the classical diffusion theory, which he referred to as the "center-periphery model." According to Schon (1971), the assumption that innovations originate from a centralized source and then diffuse to users fails to capture the complexity of decentralized diffusion systems in which innovations originate from numerous sources, are shared among individuals, and evolve as they diffuse via horizontal networks. In such decentralized systems, innovations pop up from users at the operational levels (as opposed to the core) and new ideas can spread horizontally via peer networks, with a high degree of re-invention occurring as innovations are modified by users to fit their conditions. The topology of decentralized systems shares a remarkable resemblance with social networks, which allow information diffusion to be widely shared by adopters who also serve as their own change agents (Centola, 2010; Gibbons, 2007).

Diffusion of innovation theories thus comprehend a spectrum from centralized, information diffusion systems to decentralized, horizontal networks. Rogers (2010) argued that centralized diffusion systems were defined by a top-down diffusion from governmental agencies and technical experts to local users and often displayed a low degree of local adaptation and sharing of innovation among adopters, whereas decentralized diffusion systems were characterized by peer diffusion through horizontal networks and a high degree of local adaptation and sharing among adopters. These models of diffusion of innovations were subsequently revised and applied to the diffusion of new communication technologies, with Valente (1996) presenting a threshold concept to provide a social network formulation to the diffusion of innovations and Rice (1987) arguing that computer networks facilitated the diffusion of information to organizations' environments.

Based on this history, it is apparent that literature exploring the link between network structure and knowledge distribution is centered on the extent to which decentralized networks are more effective at distributing information, specialized or otherwise. The relationship between network structure and task performance was found to be dependent on the type of task performed within organizations (Ahuja and Carley, 1999; Cummings and Cross, 2003), with non-routine tasks performing better in less hierarchical networks compared with more routine or simpler tasks which benefit from hierarchy, in line with the postulates of classical diffusion of information theory. Transposed to our empirical study, we hypothesize that as the proportion of specialized information being shared

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