Formal Organizations, Informal Networks, and Work Flow: An Agent-Based Model

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Abstract. Few computational network models contrasting formal organization and informal networks have been published. A generalized organizational agent-based model (ABM) containing both formal organizational hierarchy and informal social networks was developed to simulate organizational processes that occur over both formal network ties and informal networks. Preliminary results from the current effort demonstrate "traffic jams" of work at the problematic middle manager level, which varies with the degree of micromanagement culture and supervisory span of control. Results also indicate that some informal network ties are used reciprocally while others are practically unidirectional.

Keywords: organizations, networks, ABM, boundary spanning

1 Introduction

Organizational stakeholders often articulate the importance of informal networks: "it's not what you know, it's who you know" is a truism, and managers routinely use their own networks to accomplish goals and get work done [1]. Yet informal networks are seldom studied in organizations and are often erroneously presumed to be comprehensively known and understood by managers [2]. Companies rarely undertake network analysis prior to organizational actions, sometimes with disastrous consequences.

Network scientists who publish case studies in magazines and journals advocate a network approach to managerial decision making. For example, Cross, Parise, and Weiss [3] tell a cautionary tale of an organization's office-space redesign gone wrong due to a failure to account for individuals' positions as important nodes in informal networks. Cross et al. [3] highlight successes at organizations such as the U.S. Defense Intelligence Agency (DIA) where organizational network analysis led to measurable, beneficial organizational outcomes. Computational modeling and simulation offer an abstracted and generalized methodology to study and quantify processes and outcomes that can occur as an organization's employees interact with each other to disseminate information, collaborate, or make individual decisions. Individual decisions have real organizational implications, like the choice to retire based on what others in one's network are doing [4]. The purpose of this effort is to develop an agent-based model

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(ABM) to simulate work and information flow over both formal, hierarchical networks and informal networks that cross formal organizational boundaries.

Early network studies of organizations include the frequently-cited Allen and Cohen [5] study of information flow in research and development laboratories, which compared formal organizations and informal networks, and concluded that work-related technical communication resulted from both social relations (i.e., informal networks) and work structure (i.e., formal organization). The authors also observed differences in communication by status (i.e., individuals with PhDs and without PhDs) and differences related to individuals' position in the network as "sociometric stars," which afforded them the opportunity to serve as gatekeepers of information [5].

Katz and Tushman [6], also studying R&D laboratories, found differing patterns of information flow based on whether a project was focused on research, development, or service, with research projects generating significantly more intraproject and R&D laboratory communication, while service projects generated significantly more intraorganizational communication throughout the organization. As in [5], the authors also found a specialized role for certain individuals—boundary spanners—who served as informational interfaces between internal organizational stakeholders and external stakeholders such as customers/suppliers, other professionals, and consultants [6].

Social network field studies of organizations and the people in them present specific research methodology challenges [7] and executives may be reticent to release information on the internal workings of their organizations since doing so could potentially give competitors an upper hand or put the organization at legal risk. Perhaps the most well-known social network dataset in recent years that details information flow in an actual organization is the public release of the emails of 158 employees of the Enron Corporation in 2002 following the federal inquiries after Enron's demise. Diesner, Frantz, and Carley [8], in a study using the Enron email data, praise the email corpus as being, "alluring and of particular interest with much academic value…a rare, authentic glimpse into the social network of an actual business organization" (p. 202). The authors enhanced the Enron email dataset by adding previously unknown names and producing much higher rates of email-to-individual mapping before they extracted social network data. In addition to enhancing the dataset, the authors found that the flow of information between employees diversified with respect to formal roles as the Enron crisis intensified, previously disconnected employees began communicating, and formal chains of communication were bypassed [8].

2 Computational Network Models of Organizations

A few scholars have modeled information flow in organizations using formal, mathematical models and agent-based models. Ben-Arieh and Pollatscheck [9] developed a model using dynamic programming linking hierarchical organizational productivity to information processing, finding that "information overload" caused declines not just in individual productivity, but also in overall organizational productivity. By running sensitivity analyses to optimize the parameters of information compression and information expansion across three hierarchical organization types—

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homogenous, semi-homogeneous, and non-homogeneous—they concluded that the higher the cost of information processing, the lower the amount of information should flow [9]. To validate the model, a pilot study was conducted in a real-world "high-technology communication company" which tracked information flow between levels, finding that information mostly flowed downward with only 28% of information flowing upward from middle management to the top. The authors noted interest in their model from the military intelligence community as an additional indication of validity, classifying that community solidly as an organization with homogeneous information flow [9].

Using agent-based modeling and dynamic network analysis, Lin and DeSouza [10] took a different approach to exploring information transfer in organizations; essentially, a "bottom-up" approach in which agents formed ties based on individual utility maximization, leading to the emergence of informal social networks. Highly knowledgeable individuals had a tendency to have fewer network connections, possibly due to the high cost of being a constant source of information to others [10]. High knowledge diversity in an organization led to good reachability in the informal networks that emerged, and when knowledge is diverse or becomes obsolete fast, interpersonal, relationship-based knowledge transfer is less effective at improving the average knowledge level in the organization [10].

Tsvetovat and Carley [11] constructed a multi-agent, network model of organizations—in this case, covert networks representing terrorist cells—on the premise that complex socio-technical systems like organizations can be modeled only by combining social networks and cognitively-plausible agents acting independently. The agents are bounded in their rationality and their information about the world is limited by their ability to perceive. More simply, an individual agent only knows what it knows from its own small corner of the world: it knows only the other agents in its ego network, and knows only about assigned tasks and resources, though it will attempt to form beliefs about other agents and what they know. Communication occurs as a function of social proximity, homophily, and need, and agents exchange knowledge and learn about other agents to execute complex tasks that require coordination and delegation between agents [11]. To prove the viability of the approach, a terrorist cell network was generated from known, empirical network statistics and a corresponding anti-terrorist team was tasked with discovering and then exploiting knowledge about the terrorist agent activities in order to successfully disrupt the network [11].

These network studies of organizations have demonstrated the important role of informal networks and the particular importance of boundary spanners who connect different teams or parts of the organization though they have no direct linkage in the formal, organizational hierarchy. Few computational network models contrasting formal organization and informal networks have been attempted, and those that have are often calibrated to a particular case study (e.g., Enron). A generalized computational organization model containing both formal organization hierarchy and informal social networks, including boundary spanning, is needed to simulate organizational processes that can happen over both formal network ties or informal networks, permitting the precise quantitative measure of when each (simulated) network tie is used.

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3 Methods

Developed in NetLogo [12], a simulated organization is populated with employee agents at multiple levels (e.g., CEO, managers, workers) and at each time step agents carry out work tasks that require them to interact with other agents to receive and complete projects, similar in spirit to the manner in which Tsvetovat and Carley's [11] agents used their ego networks to gain access to needed knowledge.

The simulation of informal networks in the current study uses a simple Erdős–Rényi random network mechanism [13][14], where each pair of nodes is connected with some probability P (typically set at 0.01). While alternative network mechanisms (e.g., Watts-Strogatz small world) may better represent the nonrandom nature of informal organizational networks, the goal of this simulation was to examine a network topology that contains both formal, hierarchical links, along with some number of informal network links such that agents are connected by more network ties than just those shown on the organization chart. With the existence of the informal network, employees can leverage informal ties to reach across organizational boundaries to complete their work.

Outcome measures of interest included task performance (i.e., completion, efficiency) and measures of information flow and work movement. The percentage of information flow occurring through the links that define the formal organization is also compared with the percentage flowing through informal network links. If work gets "stuck" in the hierarchy, for example, can agents work around the blockage?

Calibration data were sourced from [9] and Table 1 lists the model parameters and sample values used in this simulation. Empirical data like the [9] pilot study on the amount of information sent and received by organizational level permits one to adjust the "bottleneck" parameter B such that some agents' workloads—for example, those of middle managers—might become overloaded as the model runs, creating further delays in the transmission of work or information to subordinates and preventing work from flowing back up through those middle managers. Acknowledging the fact that a disproportionate amount of information flows downward and horizontally, as opposed to upward, the upward transmission constraint *U* determines the likelihood/possibility that an agent can go "over the head" of a middle manager to the next level up.

Table 1. Parameters for org networks agent-based model.

Parameter	Description	Sample Values
S	Supervisory span of control	5, 10
P	Probability of rewiring (informal network)	0.01, 0.03
B	Bottleneck (i.e., micromanagement)	0.1, 0.5
U	Upward constraint on information transmission	0.90, 0.99

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4 Results

Several hundred model runs were conducted to compare conditions – notably, the presence or absence of the informal network. The primary finding is the strong effect of the bottleneck parameter on organizational efficiency. The Bottleneck parameter (i.e., time managers spend on work as it transits down and up) interacts with span of control: with high bottleneck and high span of control, managers simply have too much work to do and tasks essentially get stuck at the manager, decreasing the efficiency with which employees receive new work. Work completed by employees is also approved more slowly. When middle managers are overwhelmed, employees more frequently utilize the option to "skip" their manager and go directly to the CEO, if allowed. However, when the bottleneck parameter is low and the organization is efficient – even with a moderately high span of control of 10 – employees rarely skipped their manager.

Efficiency, a metric calculated as the ratio of work units to units of time expended, was not improved by the addition of the informal network, though this is likely an artifact of the model's current implementation. Currently, the CEO has perfect information on the entire organization's workload and continues assigning work to maintain the workforce utilization level. In reality, the CEO's imperfect information would decrease efficiency, and this modification is planned for future model development.

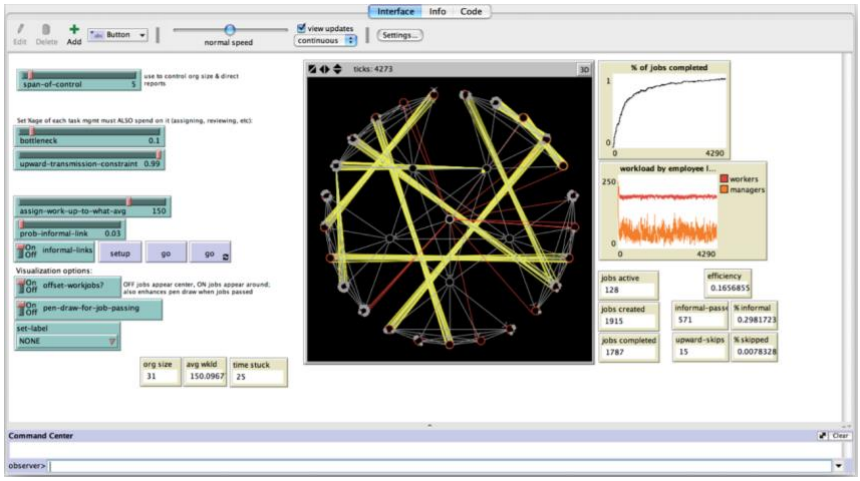

Fig. 1. Org Network Model. S=5, P=0.03, B=0.1, U=0.99 after 11 simulated years

Qualitative findings were explored using real-time model visualization. Figure 1 displays the GUI of the model showing a single model run after 11 (simulated) years, displaying use of informal network ties (yellow) to pass work. In Figure 1, the worker near the 8 o'clock position has passed many jobs to a friend at the 10 o'clock position, but the cluster's triangular shape indicates that the 10 o'clock agent has not made the same use of the informal network tie. However, the 10 o'clock agent has an informal

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connection to the manager of the team in the northeast quadrant and has apparent passed a substantial number of jobs to that manager to then be funneled to the CEO.

5 Conclusions and Discussion

The primary goal of the current effort was to generate an organizational network topology that considers both formal organization (hierarchy) and the informal networks that emerge in work organizations and to explore work flow over these co-occurring networks. A second goal was to lay the groundwork for future modelers to simulate "organizational life" on co-occurring networks. Such models permit studying how the process of information flow is affected by network characteristics as individuals participate in groups and in the larger organization.

Preliminary results from the current effort demonstrate "traffic jams" of work at the problematic middle manager level. When this occurs, employees end up with very little work to do because their manager is too busy processing work coming from both directions (up and down) to assign new tasks. This result depends greatly on the organization's "bottleneck" parameter. However, if employees are appropriately empowered, middle managers spend minimal time preprocessing or post-processing work. In a more risk-averse organization, middle managers spend substantial time micromanaging the work, decreasing efficiency and increasing employees' need to use their informal networks just to get their jobs done. Observing the visual path and frequency at which work projects travel over the informal network illustrates that network ties are not always utilized reciprocally – the network tie can appear to be almost unidirectional, though it's unlikely such a one-sided exchange would occur in real organizational life.

Limitations. Deliberate choices kept the model parsimonious. Agents did not differ in performance, which does not accurately represent the true distribution of performance. Introducing variability in performance may alter the dynamics of the entire organization; doing good work often begets more work, so if a given team happened to be "high performing," perhaps that team might serve as a conduit to pick up the backlog from lower-performing teams. The truly dynamic nature of organizational composition was not represented in the current model, but future work could simulate organizational growth, turnover, and personnel movement. An annual growth or contraction parameter, *G*, could control the addition of new agents/nodes or the replacement rate of agents who turn over. Networks should also be treated and implemented as dynamic [15].

Many questions remain and new questions have been raised in the current effort. What degree of connectivity, for example, is enough or is ideal to enable employees to work around middle-management bottlenecks or vacant managers, but not so much that the cost of maintaining network ties exceeds the value to be gained? What is an optimal network architecture to balance complexity with efficiency and performance [16]?

The current study demonstrates that a relatively simple ABM can be employed by researchers to simulate organizational life and to explore the use of various network connections that bridge or span network groups. The model can precisely quantify

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which work tasks were passed along which network ties at what time and under what conditions, providing rich and detailed data not easily gathered from real organizations. This initial examination of how informal networks are used when the formal organization hierarchy is unavailable demonstrates both the power and importance of informal networks. If the informal network did not exist, organizational efficiency would be negatively impacted and, at least in some places, work might nearly grind to a halt.

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