ELICIT Experiments and the Impact of Communication Networks on Decision-Making in Social Networks

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Abstract

Network science studies complex networks, studying the relationships between social networks and communications networks. Currently, there is a lack of quantitative models of metrics within social networks, particularly when considering communication network effects. In this paper, we consider the effect of communication network parameters and their effect on a decision-making task. We propose an information value metric to measure the quality of service provided to the decision-making nodes and their ability to obtain situational awareness. We conduct these experiments within the Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust (ELICIT), a command and control (C2) experiment platform. These experiments are conducted with the use of sensemaking agents developed for use in ELICIT experiments. We present results from agent-based experiments that demonstrate the relationship between communication networks and performance within social/cognitive networks.

1. Introduction

A primary area of interest in the field of network science [1] is the study of complex networks. Complex networks may be comprised of communication, information and social/cognitive networks. Currently, there is a lack of quantitative models of the interaction and relationships of these networks, especially the interaction between the layers of the complex network. Establishing suitable models will enable the development of models to predict and optimize metrics within the layers of the complex network. Specifically for tactical networks, predictive models can support the Soldier by specifying communication network quality of service parameters which will lead to optimal Soldier performance metrics such as situational awareness and decision-making ability.

Being a very broad and complex topic, we consider a specific scenario to analyze the effect of communication network parameters on decision-making ability. We consider a group of users who are performing a particular decision-making task and measure the impact of variable communication network quality of service. Our experiments make use of the Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust (ELICIT), a command and control (C2) experimental platform designed to determine the effect of organization to carry out a shared situational awareness task [2]. By varying parameters of a simulated communication network, we can measure the change in performance of the group.

In organizations, the flow of information is important. Without the necessary information available to the correct decision makers, performance of the entire organization will suffer. This is more apparent in current technology as the flow of information is more distributed than ever. Centralized hubs of information have given way to distributed sources of online information passed on through social networks. Within the tactical environment, this is also the case with C2 databases such as TiGRNET, FBCB2, which potentially provide immense amounts of information to the Soldier.

However, the situation in these networking scenarios is that the correct amount of accurate and timely information needs to be provided to the user. For each of these requirements for information, the consequences of not receiving the information in a sufficient manner may result in poor decision making performance and situational awareness [3]. In terms of the amount of information, too much information results in information overload and the decision-maker may not be able to find enough relevant information to make appropriate decisions. Too little information will not give the user enough to make informed decisions. Inaccurate information will cause the decision makers to make wrong decisions. Information presented too early or too late will also degrade decision-making performance. In this paper,

we consider the effect of the flow of information from a perspective of information value. We propose a metric to be used by decision-makers to determine the value of information sources in terms of the value of information generated or forwarded. We also consider the effect of communication network parameters on information value of sources.

The next section introduces the platform used for the experiments. Section 3 describes the proposed information value metric and Section 4 presents results on information value and decision-making ability as a function of communication networks.

2. ELICIT

We have used Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust (ELICIT) to conduct command and control (C2) experiments of humans and human-agent models. ELICIT is a command and control experiment platform designed to measure the behavior of social networks in a information-sharing scenario. Participants in ELICIT experiments are periodically provided with "factoids" or snippets of information. These factoids are sent and received among the participants, or the participants can retrieve information from a set of simulated websites or databases. This information is used to deduce information about a fictional insurgent threat (gaining situational awareness, the *who, what, where, when* of the threat). ELICIT was initially designed to study the organization of social networks and the interactions within these networks.

Recently, sensemaking agents were developed to run ELICIT [4], which enabled trials of ELICIT to be run without human participants. This version of ELICIT is called agent-based ELICIT (abELICIT). These agents are governed by a set of sensemaking parameters, which can be used characterize the effectiveness of the agent in processing and sharing information with other participants in the experiment. For example Anderson [5] considers the effect of several parameters (propensity to seek, propensity to share, sharing modality) on the performance of ELICIT. Agents and humans are able to participate in the experiments together; however, we only consider experiments comprised of solely agents.

It is assumed that the sensemaking agents are valid models of humans in these experiments. When considering communication networks within ELICIT, it is hypothesized that the sensemaking agent parameters can represent communication network parameters.

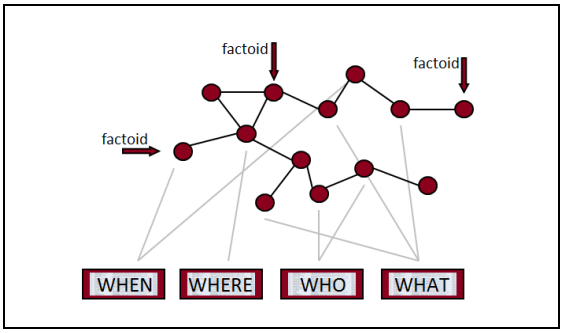

Figure 1. Structure of the ELICIT platform

To measure the performance of ELICIT, we evaluate the correctness of the group in being able to "identify" the details of the terrorist threat. The correctness measure represents a measure of situational awareness within this scenario. Correctness is measured by the accuracy of the *who, what, where*, and *when* in each of the identifies. The information for *who, what, where* are scored with 0 or 1, and *when* has a score of {0, 0.25, 0.5, 0.75 and 1.0}, allowing for partial correctness. The overall correctness score, *C*, a value between 0 and 1 is:

$$C = 0.25\,(\,who + what + where + when\,). \quad (1)$$

The sharing of information in ELICIT is done with factoids, which have varying information value. Each factoid is classified into Expert or key, supporting and noisy information. Further, given the state of the participant in the experiment (either human or human agent) the information may prove to have less value than it does on its own. A node may have already seen a specific factoid (duplicate) or the node may have already resolved the uncertainty resolved from information in a supporting factoid. These cases would lead to the awareness of the agent to remain unchanged.

3. Previous Related Work

Recent work of ELICIT has studied the sensemaking agents within the experiments. A study of the validation of these human agent models to match human behavior has been done [6]. Additionally, we have simulated communication network parameters through the use of the sensemaking agent parameters [7]. Our current results include the characterization of the joint effects of loss and delay in a distributed networking and distributed-server scenario.

Figure 2 shows the average correctness vs. information delay for 1 and 2-hours. Figure 3 shows the average correctness vs. information loss for 1 and

2-hours. The tolerance to loss is shown comparing these two figures.

Additionally, the effect of scalability and connectivity on the performance of the network was studied. We have also observed an information overload phenomena in certain cases, where the performance of the human agents is degraded due to the inability to process incoming messages fast enough. This is shown in Figure 4, where the number of shared information packets in each 5-minute interval is shown. The nodes have been distributed into an area of unit area, and a link between two agents is established if they are within distance *r* of each other. It is seen that for sparse network topologies the agents are able to process all the information whereas the dense network topologies suffer from information overload and average performance degrades. Thus far, our studies involve the use of human agent models. Future work includes the identification of suitable populations to carry out these experiments using human subjects to determine the validity of these findings as well as to find additional trends and behaviors which are not present in the human agent models. Also, we are interested in studying trust relationships and the flow of information within these scenarios.

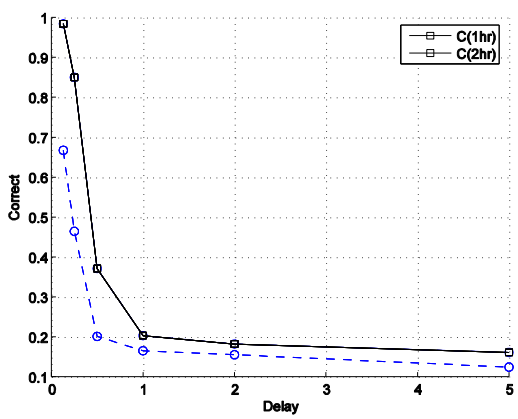

Figure 2. Correctness vs Information Delay for 1 hour and 2 hours. Loss = 0%.

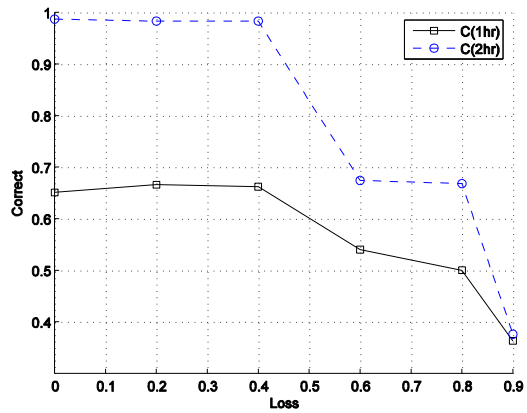

Figure 3. Correctness vs Information Loss for 1 hour and 2 hours. Delay = 8s.

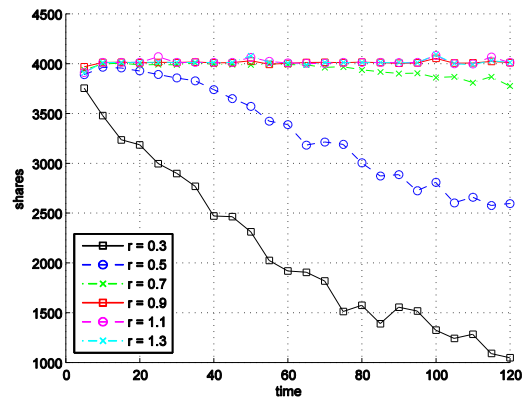

Figure 4. Number of shared information packets per 5-minute interval for various network connectivity.

3. Information Value

According to the information value classification of the factoids, we consider weighting the amount of information provided from each information source. To maximize performance, it is important to identify the sources of information which are providing the greatest amount of information. With limited resources (time and bandwidth), this may be a key factor in the performance of the organization. Being able to filter out poor information sources may alleviate the information overload problem.

Over time, each information source will forward factoids to its neighbors, and the contribution to the organization can be quantified by the amount of useful information it provides. Forwarding or sharing expert (*E*) or supporting (*S*) factoids will benefit the organization, while noisy (*N*) factoids will prevent useful information from being processed. The agent is able to determine the value of the information based on the raw information in the factoid and the

information that the agent already possesses. We propose the following information value metric:

$$IV = \frac{\alpha_E E + \alpha_S S - a_N N}{P} \qquad (2)$$

where the weights α_E, α_S, α_N are assigned to E, S, and N, respectively, to reflect the information value to the organization as a whole. We define P to be the total packets received. This metric can be evaluated as a function of time. Our assumption is that the weights are based on the raw measure of information in the factoid. Even though a factoid may contain redundant information or be a duplicate, it may be of value to other neighboring agents. These factoids may reinforce information or relationships; however, this concept is not used in these experiments.

The information value metric will show a raw measure of the relative information value being sent by each individual node. Being able to identify which nodes are sending out valuable information may enable decision-making nodes to give preference to processing incoming packets from desirable neighbors or conversely ignore incoming packets from nodes with low *IV*. This metric is an objective measure of information value. In other words, the relative value of information is measured. For example, a node may receive an expert factoid from a neighboring node, but it may be of no value since the receiving node may already have this information. Additionally, we may consider the case where different nodes have different objectives, causing decision-making nodes to have different *IV* opinions. Nodes may also assign different weights to the information packet classifications.

4. Experiment Results

We ran a set of ELICIT experiments with a network size of $n = 51$ and randomly placed the nodes into a unit area. A link was formed between two nodes within radius $r = 0.3$. The factoids were randomly seeded into the network at $t = 0$ without duplication. The websites were not used so that the task was completely distributed. For the information value metric, weights of $\alpha_E = 5$, $\alpha_S = 2$, $\alpha_N = -1$ were used. This set of weights emphasizes the value of expert factoids while penalizes the forwarding of noisy factoids. Figure 5 shows *IV* for an ELICIT experiment. The high *IV*, average *IV* and low *IV* for the run are shown. The simulation result shows a significant amount of variation of the *IV* metric as a function of time. Additionally, we show in Figure 6 a histogram of the final *IV* values for the simulation. A spread from around $IV = 0$ to $IV = 3$ is exhibited.

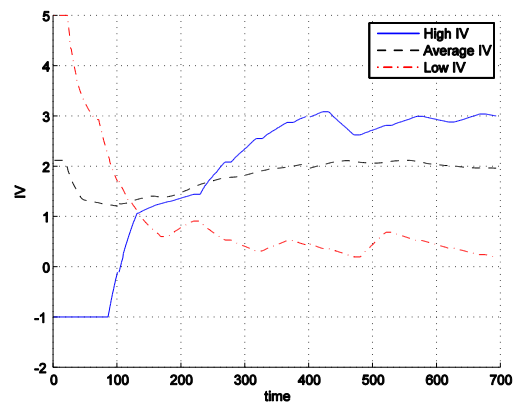

Figure 5. Information value vs. time showing high, average, and low information value.

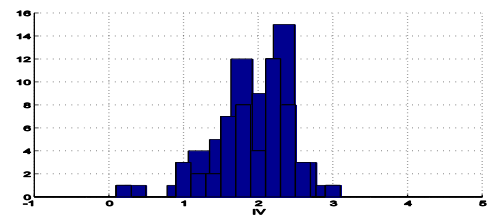

Figure 6. Histogram of final information value value for organization.

5. Conclusion

We have described an approach that considers the interactions of a complex network consisting of communication and social networks. We have considered the effect of communication network parameters on human performance metrics (decision-making). A metric for information value has also been proposed. Currently, we are working on improving the fidelity of the communications models used in the human-agent experiments. This will involve the use of a wireless emulation environment and EMANE [8]. We are also in the process of validating these results with human subject tests, to verify the behavior of the agents within ELICIT.

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