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Opinion dynamics in networked command and control organizations

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HIGHLIGHTS

- Opinion dynamics models of a multi-leveled command and control (C2) system is proposed.
- Network opinion dynamic model is divided into homogeneous and heterogeneous aspects.
- Detailed simulations of the two models are carried out and conclusions make sense.

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ABSTRACT

An opinion dynamics model for a Command and Control (C2) organization is essential for simulating combat system effectiveness. However, few studies have addressed opinion evolution in C2 simulation. With the goal of overcoming this research gap, this paper proposes an opinion exchange model, which is illustrated through a practical example of an Armored Division network. The model is divided into homogeneous and heterogeneous aspects: the former is mainly characterized by communication rules and types, while the latter is extended with the influence of multi-level opinion leaders. After carrying out the simulation of the two main models, the results show that the opinion evolution of the hierarchical leveled C2 organization with descending influence is much more complex and unpredictable than that of social networks.

1. Introduction

Iterated opinion evolution (or opinion dynamics) models are essential in simulating the decision-making processes of military Command and Control (C2) systems. This is because hierarchical layered C2 commander agents hold changing opinions in the context of time-varying battlefield situations. To gain consensus and facilitate engagement synchronization, all the agents must communicate and form convergent opinions. Therefore, it is necessary to build the *Opinion Dynamics* model that can effectively reflect C2 opinion exchange and communication behaviors.

Opinion evolution simulation can be classified into the intelligent aspect (i.e., decision modeling) of combat systems, which addresses organization communication, and interactions in decision-making processes. In other words, opinion evolution is a sub-module, which ensures collaboration and action synchronization in the decision and engagement of the commanders.

A previous study [1] has worked on a normative methodology and computational framework to assess the effectiveness and efficiency of C2 organizations. That work addressed how C2 agents managed coordination efforts to achieve effective use of available resources, but did not present an opinion exchange model. Another work [2] proposed an Intelligent System Modeling and Simulation Language (IMSL), and provided a cooperative attack allocation planning rule with IMSL. A large-scale real-world military deployment planning problem has also been presented [3], while another work proposed a new approach to the problem of interoperating military command and control with Battle Management Language (BML) [4]. Another previous study [5] has pointed out that the military mission makes collaboration and coordination key capabilities

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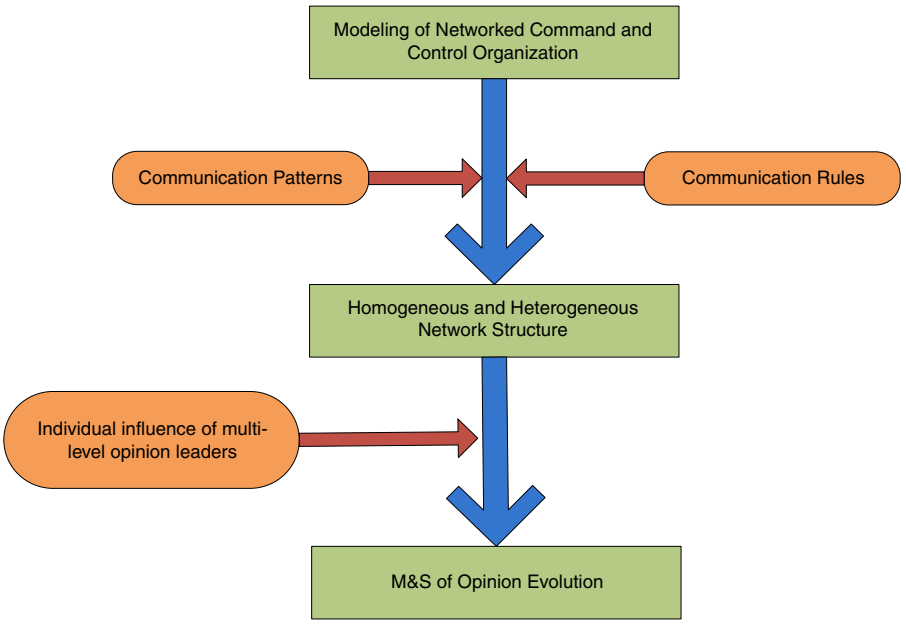

Fig. 1. Framework of the paper.

for C2; this work also presented a conceptual intent and effects model as well as a formalism that is interpretable through both human and machine. Nevertheless, although these works are useful for modeling C2, they did not address the topic of opinion communication models.

Therefore, in this paper we conduct preliminary research on opinion communication models of a networked C2 organization. The structure and framework of the model is shown in Fig. 1.

The remainder of this paper is divided into sections. A recent study about opinion evolution in social networks is presented in Section 2. In Section 3, a C2 Network Organization Model of the Armored Division is established based on the practical commanding relations. A basic opinion evolution model of the C2 network organization is proposed in Section 4 based on the C2 networked model. In Section 5, the opinion evolution of a homogeneous C2 network (i.e., all agents have the same levels of tolerance, acceptability, and influence) is modeled, and the communication results are analyzed. In Sections 6 and 7, the extended leader influence-based opinion evolution model of the heterogeneous network (i.e., hierarchical agents have different levels of tolerance, acceptability, and influence) is built, simulated, and analyzed. Finally, the conclusion is presented in Section 8.

2. Background—*opinion dynamics models*

Opinion evolution, or opinion dynamics, refers to the evolutionary process, in which a group of interacting agents changing their opinions by compromising with others. We have many examples of opinion evolution in daily life, such as those that occur in family affairs, discussions between a husband and wife, as well as those involving national economic policies and merging divergent opinions of different countries. Due to the potential applications in social and political science, research on public opinion formation has been increasing in favor for a long time, and numerous mathematical opinion dynamics models have been developed [6–10]. Opinion dynamics models can be classified as discrete or continuous, depending on the representation of opinions with either discrete or continuous values. Well-known discrete models include the Voter model [11,12], the Sznajd model [13,14], the Social Impact model [11], the Axelrod Culture model [15], and the Rumors model [16,17]. Examples of continuous opinion dynamics models include the Deffuant model [18,19], the Hegselmann–Krause model [20], and the CODA model [21,22]. The first two models are bounded-confidence models [23] with similar opinion representation (i.e., a continuous variable) and opinion exchange (i.e., agents only influence one another when their opinions are close enough). The two models, however, differ in the opinion update rule, which characterizes whether agents interact with compatible neighbors one-by-one or all at once [24]. The CODA model is a hybrid approach where agents hold continuous opinions as in the bounded-confidence model but make binary decisions. Following Bayesian rules, agents update their opinions based on the observed actions of their peers [25]. These classic models and their modified versions have been widely applied in exploring public opinion formation and social contagious behavior.

In addition, two-party and three-party voting models of opinion dynamics have been studied by Galam in Refs. [26–29]. Earlier works [26,28] have addressed the effect of majority rule voting in hierarchical structures using the basic concepts from a real space renormalization group. Moreover, the Random Field Ising model approach has been discussed in Ref. [27]. Recently, the drastic effect of local alliances in three-party competition on democratic hierarchical bottom-up voting has