Analysis and Control of Socio-Cultural Opinion Evolution in Complex Social Systems

Farshad Salimi Naneh Karan and Subhadeep Chakraborty

Department of Mechanical, Aerospace, and Biomedical Engineering,
University of Tennessee, Knoxville, Tennessee

Motivation and Problem Description. Humans have always interacted with each other, either in small social groups such as a circle of close friends, or larger social settings such as social media networks, and hence have likely always been attuned to the preferences and positions of others. At the same time, we have evolved sophisticated sensory systems and brains capable of reaching independent conclusions about the world. Therefore, in our efforts to function effectively, we have likely had to balance our own experiences, ideas, and beliefs with those of others with whom we interact (Fig. 1.)

The objectives of this research are (i) to develop a Probabilistic Finite State Automata (PFSA) based discrete choice model (DCM) for individual perceptions and judgments, based on social psychology theories on disparate motives, attitudes and persuasion processes to explain individual-level behavior; (ii) through a study of DCMs interacting over various (Voter, Sznajd-Weron, Krause-Hagselmann bounded confidence) interaction models imposed on several network topologies, to develop analytical tools and numerical simulation platforms for investigating how local interactions between social agents create order (consensus or divergence) out of an initial disordered situation; and (iii) investigate how such a process can be potentially controlled by manipulation of perception (cognitive hacking) exercised by strategically placed 'influencers'.

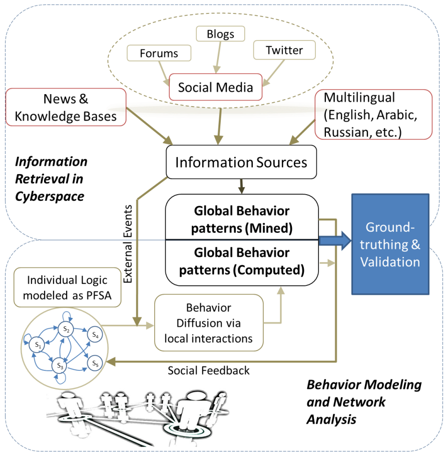


Fig. 1: Graphical representation of people's social interactions, information resources, and decision making processes

Background and Limitations: Despite vast diversity in the field of judgment and decision-making, major theoretical concerns of agent-based models are mostly related to the historically dominant expected utility family of theories made popular by von Neumann & Morgenstern [1]. In contrast, a statistical physics approach to social behavior [2] deals with a single basic question of social dynamics: how do local interactions between social agents create order out of an initial disordered situation? Due to its similarity with constitutive equations describing the Ising model and the Mean Field theory (among others), tools developed for statistical physics, such as the Ising model as well as non-equilibrium statistical models have been used extensively to model the spread of influence in a networked society.

We believe that either approach, individually, is incapable of addressing many of the important questions in socio-dynamics. The often-used Ising model paradigm of simplistic interaction rules (e.g., blind emulation of peers as in the Voter model and its derivatives) is unrealistic, while social psychological research is rarely employed in representatively large scales.

Novelty and significance: The main research hypothesis of this project is that, group level diffusion of opinions and ideology can be modeled and analyzed using discrete choice models for individuals interacting via gossip, and this opinion diffusion process can be controlled or at least contained using strategically placed influencers. This is systematically studied by exposing a society to inflexible agents (called influencers, zealots, etc. in literature) who never change opinions but do alter the dynamics of opinion evolution. In past publications, the authors have shown that by using such moderating agents the system can be forced to approach desired global behavior [3]. Nevertheless, so far, the placement of these control inputs has been random. We believe that a more methodical approach is very much needed to deal with this problem; techniques borrowed from control theory should provide us with the necessary tools to address the said issue.

Contribution and Approach. The first contribution of this research is to establish a mathematical foundation for analytical solutions of opinion evolution through Voter-model type interactions in presence of zealots. The accuracy of these mathematical solutions are assessed by extensive numerical computations. Mathematical models in this study rely on the Master Equation [4]. One of the preliminary results of this objective is "Dynamics of a Repulsive Voter Model" (**RVM**) [5] ; where agents with similar opinions repel each other. Mathematical modeling and numerical analyses are conducted on the system's controllability and time evolution of the proposed model. The accuracy of the modeled system is shown in Fig. 2.

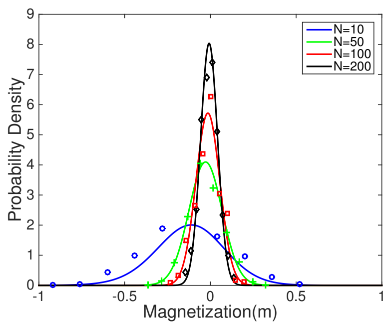


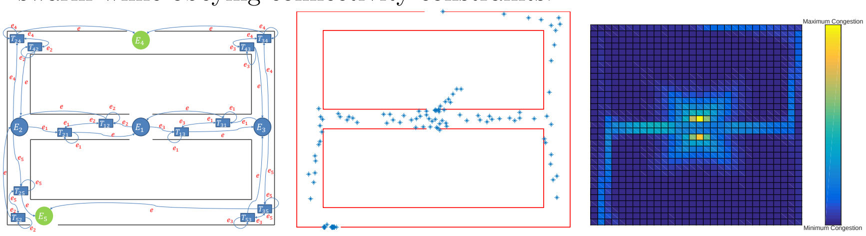
Fig. 2: Effect of the population size

Social computations, although successful in exploring characteristics of a society as a whole, ignores individual level behavioral dynamic. Integrating individual level decision making algorithms into social computations to compensate for the available shortcomings is another objective of this research. In this research, decision making is modeled as a PFSA. A few publications by the author related to this area can be found in [6], the paper accepted to the SBP-BRiMS 2017, and one other study submitted to the Journal of Artificial Societies and Social Simulations. In these studies, too, controllability of the systems is discussed.

Application. Methods developed in this research can also be used for:

a. **Traffic Simulation and Connected Vehicles: RVM** is capable of predicting the behavior of a group of drivers in a two-lane road [5]. Currently, the authors are analyzing actual traffic data to show the practical suitability of the proposed model. The author intends to expand the idea of traffic simulation to the field of connected vehicles. Another potential application is to model the interaction between vehicles in a vehicle platoon.

b. **Multi-story Building Evacuation:** the authors were able to mathematically model the egress dynamic of a large group in buildings in states of emergency [7]. Also, in a new study, agents are given decision making abilities (MDP). Fig. 3 illustrate the used MDP setup (a), chosen paths by agents (b), and the congestion heat map (c). The author hopes to further develop this area of research to increase the safety of large buildings and save lives in emergencies by developing control techniques to see if such stochastic systems can be guided towards desired exits. "**Circumcenter Control**" from robotics literature have proven to achieve rendezvous among the robotic swarm while obeying connectivity constraints.



(a) (b) (c)

Fig. 3: Egress simulation setup of a large building with two exits

c. **Advertising and Marketing:** Simulation of the evolution of online information could enable a deeper understanding of customer behavior.

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