Network Science Center at West Point

Project Brad-Net: Understanding Complex Network Systems and Organizations

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Project Brad-Net seeks to organize and control the complexity of networked systems and organizations to understand how to exploit it for effectiveness. We build both theoretical frameworks and applied models that embrace and reveal the complexity of these systems. We are taking an interdisciplinary, multi-perspective approach, and mainly use game theory, graph theory, dynamical systems, probability, computational structures and processes, simulations, visualizations, natural language processing, and data analytics. Our models and theories are based on human-inspired or human-based metrics for effectiveness, efficiency, cooperation, competence, trust, flexibility, agility, adaptability, versatility, responsiveness, intelligence, enthusiasm, robustness, and resilience. We have collected network data from the field and will be collecting more to both validate our results and motivate our research. Because of our unique situation of having team members deployed in operational contexts, we intend to test results in operational environments. We named our project for General Omar Bradley, former faculty member of the USMA Department of Mathematics and advocate for modeling the complexity of military operations.

Objectives: This project seeks to understand the issues associated with the following questions and to build models and simulations to analyze network, system, and organizational behavior.
1) How do we make systems and organizations better?
2) How do we make entities (network nodes, system components, organizational members, robots, computers, people, staffs, decision-makers) contribute more value?
3) How do we produce tools to enable leaders to build, manage, lead, analyze, and understand their systems and organizations?
4) How do we understand situations, build awareness, and use information effectively?
5) How do we ensure effective decisions are made and implemented?
Our main thrust will use mathematical inquiry associated with all our models to contribute to the development of the emerging science of networks. Our work will focus on the depth, rigor, and applications relevant to our theoretical frameworks and theorems. Our thrust is to move toward rigorous theories and algorithms that also lend themselves to explanatory and predictive models and robust social network analysis tools.

Approach:
The concepts of subset team games, subset utility functions, and cooperation space were introduced in a paper presented at the 2008 Army Science Conference (Arney/Peterson). This framework suggested that cooperation space might provide a useful analytical tool for understanding the nature of cooperation within various kinds of scenarios involving multiple players in networks, systems, and organizations. The fundamental assumption underlying the theory is that a notion of utility exists not just for single players or the entire group, but for all subsets of a collection of players. While subset team games are defined in the language of game theory, cooperation space has primarily been used thus far as an analytical tool. It has been applied in the context of pursuit-evasion, network flow algorithms, team games, and sensor

distribution algorithms. It has become clear that one of the strengths of the theory is the affordance of additional analytical points of algorithm comparison. The simplest way to compare algorithms is to compare their performance against a particular metric (e.g. "success"). However, the notion of success is not always clearly defined, and may not mean the same thing for individuals and the team. The framework of subset team games provides an additional dimension of comparison: algorithms may also be compared in terms of how altruistic, or team-oriented, they are or how they build trust in the system.

Impact: We have assembled a strong research team that has organized itself as a network organization. We see ourselves as apprentice network scientists contributing to the development of this emerging science. We believe our project contributes to the Army's network science effort in many significant ways. Our work examines the interconnections among physical networks, communication networks, information networks, biological networks, and social/cognitive networks, while seeking to discover common principles, algorithms and tools that govern network behavior and allow for prediction of performance and explanation of network utility. The National Research Council's study on network science resulted in a list of challenges. In many ways, our work is directed by the factors in this list.

1. Dynamics, spatial location, and information propagation in networks
2. Modeling and analysis of very large networks
3. Design and synthesis of networks
4. Increasing the level of rigor and mathematical structure
5. Better experiments and measurements of network structure
6. Robustness and security of networks
7. Abstracting common concepts across fields