Network Science and Its Role in Information Systems

By Dr. Chris Arney

Society has made tremendous strides in its ability to solve challenging problems and to understand complicated issues in our information-centric world. However, there is still much more to do at all modes of understanding -- theory, modeling, application, and practice -- to better understand the many levels of perception --- data, text, information, intelligence, knowledge, and wisdom. The first decades of the 21st Century are often referred to as the Information Age, and the emerging area of network science is one of the disciplines contributing to this pro- gram of information-based sciences. Useful tools and methods related to network science that help tackle the most challenging-inferring issues include: data collecting, text mining, hard-soft information fusion, measuring utility, modeling, simulating, influencing, controlling, and optimizing. These kinds of information processing and analysis and managers focus on viable outcomes, evaluate alternatives, and make informed deci- sions. As Nicholas Negroponte, director of the MIT Me- dia Lab stated in his book Being Digital, "The change from atoms to bits is irreversible and unstoppable." Network Science affects the social realm by studying how individuals interact, cooperate, collaborate, exchange ideas, share information, provide support, and conduct business. However, there is still much more to do in developing Network Science since the application of its techniques is often sub-optimal because there is a significant lag in the theoretical underpinnings of this science.

As society maximizes its use of data collectors and sensors to produce the "Big Data" deluge and technology creates a virtual world in cyberspace, we now see our world overflowing with data and textual information that need ordering, refining, fusion, classifying, and protect- ing that takes into account not only the volume and accu- racy of these data and texts, but also the ultimate goal to influence and improve the human condition. This transi- tion from physical to information science has impacted in- teractions and social interactions. As Nicholas Negroponte, director of the MIT Media Lab stated in his book Being Digital, "The change from atoms to bits is irreversible and unstoppable." Network Science affects the social realm by studying how individuals interact, cooperate, collaborate, exchange ideas, share information, provide support, and conduct business.

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How do we perceive the various elements of this infor- mation world we live in? Data are the values, often nu- meric or digital, that collectively represent the lowest level of abstraction from which information is derived. Raw data are unprocessed and the result of direct collect- ion by a sensor. Text is formatted or translated as special characters or even unprocessed words of a written lan- guage. Information is the fusion of data and text into a message (a set of characters and words with meaning or structure). Intelligence is the result of understanding the information message by establishing its situational context and performing a reasoning or learning process on the information context. Knowledge is the result of a complex cognitive process where intelligence is organized and linked through a cognitive network by logic, association and interdependency. Wisdom is the ability to apply and reason with knowledge to reason, to create new knowledge, to make plans, to solve problems, and/or to make deci- sions. Wisdom can produce associated cognitive ele- ments of judgment and insight. The knowledge-focus perspective in the information world comes from Network Science, in particular, the merging of the informational layer with associated social and physical elements. The first volume of the new Net- work Science journal defines it as "the study of the col- lection, management, analysis, interpretation, and pres- entation of relational data." This mode of inquiry and modeling, while still in its infancy, provides dynamic structures and processes to convert information and intelligence into more usable and refined knowledge. The network layers (physical, informational, communi- cation and social) produce an all-encompassing non- reductive model that copes with multiple scalings, tremen- dous volumes of data and information, and the complexity of interdependent relationships of intelli- gence. Networks are not only ubiquitous, but also lie at the core of the economic, political, military, and so- cial fabric of modern society. As stated in the NRC report on network science, "society depends on a di- versity of complex networks for its very existence." Network Science is critical to understanding communica- tion flow, developing command and control, managing organization behavior, implementing information assur- ance and security, and creating new knowledge in situ- tational awareness. One of the recent results in Network Science shows the impossibility of perfect control over organizational and entity behavior in social networks. A subtle hand of deliberate management through vision and autonomy is often more powerful than rigid micro-control through rules, regula- tions, and detailed instructions.

A strictly reductionist (data and statistical analysis) approach to information science produces barriers to full understanding of information. By embracing com- plexity with non-reductive problem solving approaches, network science allows us to better understand the implications on the systems science contributes to solving society's toughest challenges and deepest mysteries. Network science seeks to help model and capture the just-emerging qualitative aspects of information process- ing that entail the social science elements of historical nuance, cultural influence, cognitive limitations, and ideological bias. The information world is highly inter- disciplinary and thus difficult to describe, understand, or characterize even through the powerful perspectives and methodologies provided by network science.

How do the emerging patterns of network science impact the military? What directions should we take to advance military doctrine and sys- tems to improve operational success? Fortunately, the US military’s research community is already a leader in this area, and progress will require our military to im- prove the mathematical and network science modelling ca- pabilities. Network Science suggests replacing the deep hierarchical structures and standardizations of the military with more dynamic horizontal organizations involving cooperative decision making, power sharing, adaptation and diversity. While this may seem a radical idea that suggests major shifts in current military think- ing and doctrine, it is already taking place in successful modern business and industry. Just as many of our military missions have evolved to a full spectrum array that includes stability operations, cyber warfare, peace- keeping, disaster relief, and humanitarian aid, it may be time to evolve the very principles of military operations as we adapt to the operational and strategic threats that are changing to include more informational elements. In today’s mind over matter world, it may be time to wor- rie if collaborative decision-making might not be better than unity of command and embracing the complexity of warfare by reliance on autonomy and networked systems may be more advantageous than the alternative of making operations plans overly simple and detailed. While perhaps these controversial questions may not be considered practical by current military leaders and planners, they deserve further study and analysis. It is incumbent upon the network science researchers to continue to live their maxim: “It’s the questions that drive us.”

References