Performance Measures for EOs: A Preliminary Report

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Edge Organizations

- An alternative to traditional C2 structures conceptualized by Alberts & Hayes (2003)
- Main Features
  - peer-to-peer connectivity among nodes
  - pull rather than push models for information transfer
  - high situational awareness
  - dynamic resource allocation
  - distributed intelligence
- Limitation—oversimplified assumptions
  - peers are capable of processing multiple forms of information, in very short time intervals
  - peers are empowered in decision-making
  - peers are identical in capabilities and are fully connected

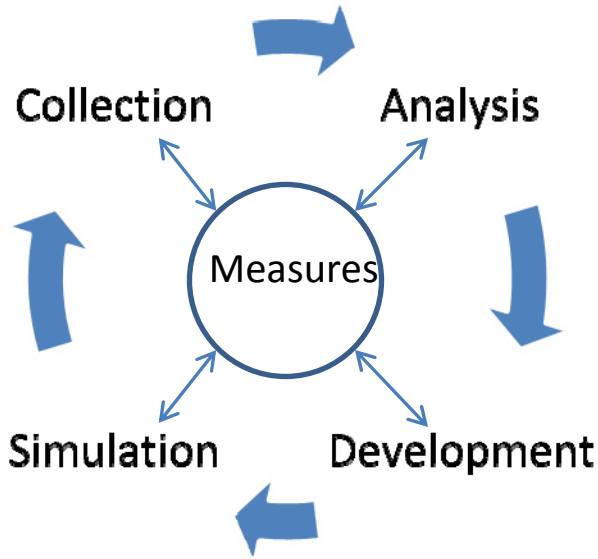
Our Project

- Major purpose—develop performance measures for EOs
  - Take an information-processing view
  - Make more realistic assumptions for application
  - Appreciate extant performance measures of other related disciplines
- Other purposes
  - Develop performance measures for general socio-technical networks
  - Understand the governing dynamics of information networks

Research Question

- How can we measure the performance of EOs?
- Our assumptions of an EO:
  - A hybrid (edge + hierarchy) C2 structure being agile in a dynamic environment
  - A distributed organization with severe communication and information processing requirements
  - A socio-technical (human-electronic) network with information transfer as the central function
- Develop measures based on these assumptions
  - First-order, e.g., organizational structure, information flows
  - Second-order, e.g., power distribution, information-processing capabilities

Research Methods



- Collection to simulation in escalating order of dependence
- Four stages link with each other in a circular manner
- Feedbacks to improve successive activities in each stage

Measure collection

- Criteria for collecting extant measures from literatures
  - lead us to interesting findings on the dynamics of information flows between technical and human nodes, respectively
  - As a starting point to build measures for socio-technical networks such as EOs
- Disciplines or theories involved
  - telecommunication network, social network, decision science, information science…
- Bias avoidance by inducing groups of measures which need trade-offs
  - network design is inherently a multi-objective optimization

Telecommunication network measures

- Network topology (graph theory related)
  - *Degree*
  - *Density*
  - *Hop count*
  - *Path length*
  - *Network diameter*
  - *Network variance*
- Output
  - *Throughput*
  - *Good-put*
  - *Channel Capacity*
- Transfer Cost
  - *Delay / Latency*
  - *Load*
  - *Protocol overhead*
  - *Packet loss*

Throughput vs. Delay

- ***Throughput***: the amount of information successfully transported by a node or a channel of the network per unit time
- ***Delay***: the time for transferring complete information from source to destination through part of a network
- Both are indicators of the information-transfer efficiency of a network

- Although it is desirable to have the largest ***throughput*** and the fewest ***delay*** at the same time, this is always not the case.
- Trade-off Scenarios
  - ***Delay*** can be decreased if we increase the number of packets buffered at intermediate nodes, whose ***throughput***, however, will go down due to the reduction of available capacity.
  - ***Good-put*** can be increased if we increase the predestined amount of application-used (as opposed to protocol-used) data in a packet; however, this will increase the amount of retransmitted data in face of packet loss, which in turn increase the ***delay*** and may even reduce the ***throughput*** *per se.*

Social network measures

- Centrality (actor)
  - *Degree centrality*
  - *Closeness centrality*
  - *Between centrality*
- Centralization (organization)
  - *Degree centralization*
  - *Closeness centralization*
  - *Between centralization*
- Subgroup (actor groups)
  - *Clustering coefficient*
  - *Reachability*
  - *Structural cohesion*
- Roles and Positions (actor relationships)
  - *Structural Equivalence*

Convergence vs. Resilience

- ***Degree centrality***: measure the influence of an actor on information transfer in terms of the number of connections it has
- ***Structural equivalence***: measure the similarity and substitutability of two actors in terms of their relations with other actors, or their traits
- ***Degree centralization***: describe the convergence extent of an organization based on the degree centrality of all actors, i.e., whether the entire group is organized around a few number of influential actors
- ***Structural cohesion***: measure the resilience of a group in terms of the minimum number of its members, if removed, will disconnect the group

- Contradiction exists between the structural convergence and resilience of the organizational information-transfer network, reflecting by trade-offs of the following measures
- ***Degree centrality*** vs. ***Structural equivalence*** (actor)
  - Despite no determined relationship between these two measures, it is less likely to find a ***structural equivalent*** substitute for an actor with high ***degree centrality***.
  - A degree-central actor is independent and resistant to delay or information distortion because of multiple channel, but may cause delay or information loss due to overload. Besides, the reassignment of this actor will be hard.
- ***Degree centralization*** vs. ***Structural cohesion*** (group)
  - a centralized group is dominated by one or a few central nodes, which can be a single point of failure in that if they are removed or damaged, the network quickly fragments into unconnected sub-networks.
  - Conversely, a less centralized group is resistant to intentional attacks or random failures—the actors remained can still reach each other along unbroken network paths.

Measures from Decision Science

- Decision Maker
  - *Utility/Loss*
  - *Preference*
  - *Risk attitude (i.e. risk aversion, neutrality and preference)*
  - *Rational ignorance*
  - *Risk premium*
- Context / Situation
  - *Uncertainty*
  - *Ambiguity*
  - *Risk*
- Outcome
  - *Opportunity loss/Regret*
  - *Efficacy (reduced risk)*
  - *Efficiency*

Uncertainty vs. cost of information

- Decision making is the process of sufficiently reducing ***uncertainty*** about alternatives to make a reasonable choice from among them. The completeness of apriori information, which can effectively reduce ***uncertainty***, is the key of success.
- However, gathering relevant information for a well-informed decision requires substantial cost (e.g., time, money), which can be measured by ***EMV***, ***EV|PI***, or ***EVPI***.
- Since the primary mission of decision making is to maximizing the gain while minimizing the cost, there is always a trade-off (***rational ignorance***).

- ***Uncertainty***: A set of possible states or outcomes where probabilities are assigned to each possible state or outcome
- ***Expected monetary value*** (***EMV***): the expected outcome without perfect information. For each alternative choice, its ***EMV*** is calculated by multiplying the monetary outcomes of possible states by their respective probabilities and then add the results together
- ***Expected Value given Perfect Information*** (***EV|PI***): the expected outcome if we have perfect information before making a decision. To calculate this value: (1) choose the best alternative for each state of nature; (2) multiply its payoff and the probability of its occurrence; (3) add all the results obtained in (2) together
- ***Expected value of perfect information*** (***EVPI***): the theoretical maximum worth to the decision maker of additional information about uncertain states of nature that is absolutely unerring. ***EVPI*** = ***EV|PI*** – maximum ***EMV***
- ***Rational ignorance***: The cost of educating oneself about the issue sufficiently to make an informed decision outweighs any potential benefit one could reasonably expect to gain from that decision, so it would be irrational to waste time doing so.

Measures from Information Science

- Usability of information
  - *Novelty/Currency*
  - *Obsolescence*
  - *Representability (e.g., similarity, IDF, discriminant coefficient)*
  - *Consistency*
  - *Completeness*
  - *Credibility, reliability*
  - *Adaptability*
- Information use
  - Information retrieval
    - *Relevance*
    - *Precision*
    - *Recall*
  - Information transfer
    - *Entropy*
    - *Mutual information*
    - *Channel equivocation*
    - *Distortion*

Info quantity vs. Quality

- ***Recall***: the ratio of the amount of correct information retrieved to the amount of all correct information in some collection, reflecting the completeness of retrieval
- ***Precision***: the ratio of the amount of correct information retrieved to the amount of all the information retrieved, reflecting the purity of retrieval
- ***Consistency***: measure the extent of format and definitional uniformity within and across all comparable information
- ***Completeness***: indicate the extent to which all information needed to accomplish a purpose is included

- There is always contradiction between the quantity and the quality of information in terms of its usability and utility, reflecting by trade-offs of the following measures
- ***Consistency*** vs. ***Completeness*** (usability)
  - Collecting more data may improve the ***completeness*** of information, but will reduce its ***consistency*** and raise the cost
  - ***Consistency*** increases by excluding some or all the inconsistent data; however, ***completeness*** would suffer
- ***Recall*** vs. ***Precision*** (utility)
  - Either of them declines as the other increases
  - The reason is that high ***recall*** tends to imply false acceptance of some items, while high ***precision*** tends to imply false rejection of some.

Measure analysis

- What performance feature of EOs does it describe (e.g., robustness, innovation)?
- Is it a structural or content measure?
  - If it's a structural measure, which part of the information-transfer process (source, destination, channel, or context) is it related with?
- Is it a qualitative or quantitative measure?
  - If qualitative, can it come into any existing group of related qualitative measures?
  - If quantitative, can it constitute a function with other quantitative measures? Are there any trade-offs it gets involved in?

Measure development

- Based on desirable application features of EOs
- Possible solutions
  - Use the original measure
    - *e.g. "centrality" of a node from social network theory*
  - Modify the original measure
    - *e.g. "throughput" from telecommunication network*
  - Combine several original measures
    - *e.g. a measure of "information distortion" by combining "packet losses and delay*

Future work

- Study various network objectives using our measures and network simulation
- Iteratively improving our measurement and network model
- Integrate the notion of hierarchy into current peer-to-peer EO network
- Introduce the temporal dimension by Investigating the evolution of EOs (network structure & information flows)

Proposed outcomes

- Performance measures for socio-technical information and knowledge networks.
- A family of designs for socio-technical information and knowledge networks.
- A deeper understanding of the design of command-and-control architectures and the role of information flow within entities in the network.
- A contingency framework outlining the applicability of various designs of socio-technical networks based on internal and external environmental conditions.

Thank You

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