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Title: **Networks of Decision-Making and Communicating Agents: A New Methodology for Designing Heterarchical Organizational Structures**

Suggested Track: **Modeling and Simulation** (Sessions on Adaptive Architectures for Command and Control (A2C2))

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Abstract.

Motivation:

The optimal structure for an organization depends on the attributes describing its task and its environment (Levchuk *et al.*, 2002a, 2002b). When the information required to execute a task is lacking at a node responsible for it, and *exceptions* arise – that is, a decision-maker must communicate with a supervisor or a peer to obtain the requisite information to complete the task, the formal channels that can be used to communicate these exceptions are defined by hierarchical or legitimate lateral relationships.

As a response to volatile environments, organizations struggle to balance stability against flexibility, specialization against generalization, and centralization against decentralization (Alstyne, 1997). A traditional hierarchy has a topology that largely restricts interactions among members of the organization to direct superior/subordinate interactions and whose number of levels is determined by the limits of span of command (Alberts, 2003). Its approach to command and control is characterized by centralized planning, decomposition of tasks, and control processes that largely rely on deconfliction. Hierarchies spawn stovepipes, which are vertical, tightly coupled component organizations that are optimized for a narrowly focused objective. The systems that support hierarchies are built and controlled by stovepipes, making interoperability difficult to achieve. Furthermore, information flows in hierarchies mirror the hierarchical structure and are largely confined to stovepipes that originated or collected the information of interest.

A heterarchy is an emergent, self-organizing form that resembles a network or a fishnet. It has lateral or distributed authority, has no fixed superior DM and has bi-directional relationships among DMs. A Decision-maker may become a superior based on his/her abilities and nature of the mission. Heterarchies involve relationships of *interdependence*.

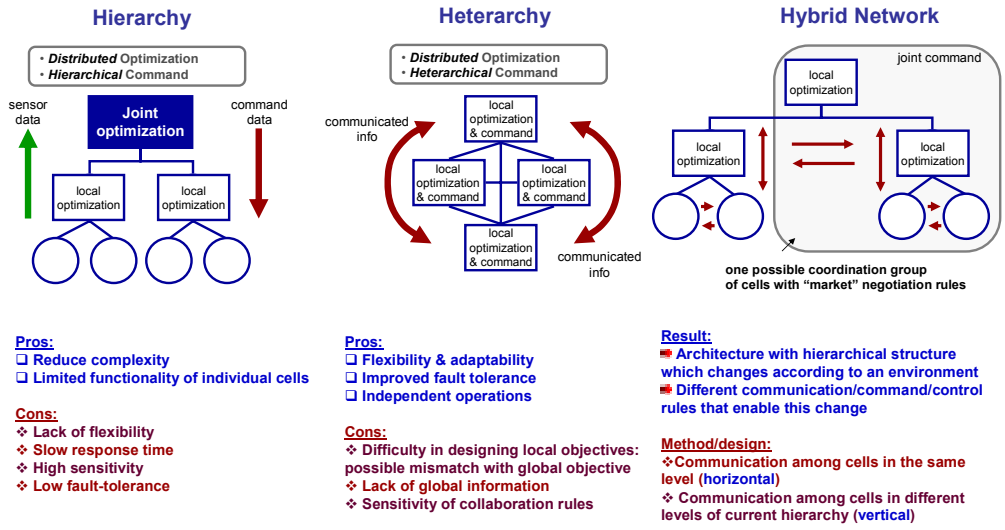

Figure 1. Example of hierarchy, heterarchy, and hybrid organization

A hybrid organization, which utilizes the beneficial characteristics of both hierarchy and heterarchy and can evolve over time, is termed a *hybrid* organization. Examples of hierarchies, heterarchies, and networked hybrid organization is presented in Fig. 1. Hybrid networked organizations encourage appropriate interactions between and among any and all members. Its approach to command and control breaks the traditional C2 mold by uncoupling command from control. Command is involved in setting the initial conditions and providing the overall intent. Control is not a function of command, but an emergent property that is a function of the initial conditions, the environment, and the adversaries. Such organizations have

attributes to be agile. This is because the agility requires that the available information is combined in new ways, that a variety of perspectives are brought to bear, and that assets can be employed differently to meet the needs of a variety of situations. Heterarchical organizations are particularly well-suited to deal with uncertainties because they make more of their relevant knowledge, experience, and expertise available.

Two prominent findings for hierarchies and heterarchies have emerged from the research on organizational behavio. First, centralized organizations were more efficient for routine tasks while decentralized networks were more efficient for tasks that required creativity and collaborative problem solving. Second, people in decentralized organizations were more satisfied with the work processes than people in centralized organizations, with the exception in the latter case that the central person in centralized networks was extremely satisfied.

Problem:

Key to the changing organizational landscape is the emergence of network forms of organization (Monge, 1995) as an integral part of the co-evolution of the new "network society" (Castells, 1996). These organizational and social forms, which are neither classical markets nor traditional hierarchies (Powell, 1990), are built around material and symbolic flows that link people and objects both locally and globally without regard for traditional national, institutional, or organizational boundaries. The changing patterns of potential threats and conflicts in today's world, together with advances in networked communications and computation, necessitate a new approach to the design of organizational structures. The volume of information and complexity of operations require that the information acquisition, processing and decision-making functions be heterarchical, distributed and dynamic over teams of decision-making entities (DMs).

The research in organizational decision-making has focused mainly on analyzing various structures and their emergent forms. The topologies of command, control and communication in organizations have been explored. However, the research lacks the methodology for analytically designing the structures congruent with the mission (or a set of missions) that an organization has to face. Moreover, the coexistence and codependence of structures with varying goods have not been thoroughly investigated. An example of such interrelationship might be a coexistence of hierarchical command structure with heterarchical control and hybrid communication network.

In this paper, we explore the decomposition of organizational processes and decision-making, and the coexistence of organization's command, control, and communication networks of various types, as well as their effects on team performance. We present a methodology to design mission-based organizational networks and rule-based adaptation strategies for network evolution.

Method:

In our previous research, we proposed a methodology for the design of hierarchical (G. Levchuk *et al.*, 2002a, 2002b) and heterarchical (Levchuk, 2003) organizational communication networks. The problem of designing command structures based on process/event-based task expansion has been explored in (Y. Levchuk *et al.*, 2002).

In this paper, we utilize the approach of process-based task expansion and rule-based command to design multi-purpose organizational structures. The approach is based on the ability to quantify the parameters of command and decision-making in project-based organizations. First, the problem is to decouple the command and control architectures to identify the information access and event-based agent process graphs. Second, the optimization rules for each decision-making node or a set of nodes are established. Next, the flow of communication between agents in the organization is quantified (including information flows, exceptions, requests/responses, etc.). Finally, the design is completed by constructing the robust communication network and flow control strategy that can support the devised team interactions.

Results and Conclusions:

In this paper, we present a methodology to design novel multi-purpose organizations with decoupled command and communication networks. The primary contributions of this paper are:

- Quantification of parameters for hierarchical and networked command and optimization;
- Decomposition of command and control structures and definition of their interaction principles;
- Mission decomposition analysis based on event- and process-driven task expansion;
- Definition of communication flow requirements based on various task-based and request-based interactions; and
- Design methodology for constructing robust and adaptive networks to support organizational interactions.

The analytic methods, applications, and measures illustrated in this paper form the basis for current research on organizational design and adaptation for large-scale human-machine systems.

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