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A Succinct Conceptualization of the Foundations for a Network Organization Paradigm

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Abstract

The paper concisely proposes a distinguishing paradigm to study a very large, collective group of agents that is called Network Organization. We will formally define and substantially evaluate this paradigm for self-governing agents, in which the state value function changes dynamically, and describe its salient properties.

When agents dwell inside an organization, they form patterns of interactions that we call *paradigms*. There are many existing paradigms to describe organizations, which affect its performance features. These paradigms include hierarchies, holarchies, coalitions, teams, congregations, societies, federations, markets and matrix organizations (Horling and Lesser 2004). Even though it is rare to find a single paradigm that is best describe an organization through its life-cycle, the best fitting paradigm (i.e., the style that best describes an organization) helps to understand an organization and recognize its possibilities. A different paradigm appears to be useful when it comes to an open multi-agent systems, where agents are self-governed by their own belief systems and have rational behaviors. This paradigm helps in modeling organizations of large firms working on giant, in scope or impact, problems that can be described as network organizations. In a previous work (Alqithami and Hexmoor 2014a), we studied an application of network organizations paradigm in order to account for spontaneous exigencies in the agents' actions to benefit and shape an organization.

Definition 1 Network organizations *(NO) are large, semi-autonomous, networked communities with the aim of automating command and control of distributed complex tasks.*

A significant step was established in the network-centric warfare that allowed oversight and control of operations from any location on the network. Network-centricity stimulates self-organization and self-integrating coordination. The US Department of Defense adopted this paradigm early on to accommodate collaboration and information resource sharing among distributed military assets and work units (Alberts and Hayes 2003). Location ignorance is extended in NO to time ignorance; therefore, operations can be controlled at any time; i.e., asynchronously. Another extension for NO is to allow any credentialed network member node to exert control on operations. In sum, NO provides a more ubiquitously open model. This openness feature may include transparent entry and exit to an organization.

An NO paradigm

The NO paradigm can model many operations. Examples are systems of river dam control, factory cells, electrical power grids, and traffic control on land, sea, and space. As a paradigm, it does not functionally alter the operations to which it is applied. The paradigm can be understood in terms of the ways it permits command and control regimes. Invariably, NO relies on a network on which it dwells. Therefore, a profile of an NO residence is essential. NO member-nodes/agents are critical constituents. Target problems (i.e., operations) modeled are important. For simplicity, we would care about flow of data, control, and coordination. The organizations may represent one or more parent institutions that govern its normative patterns of behavior. Broadly speaking, the functioning of an NO can be objective (i.e., charter-based) driven or pattern driven. Either of these could be captured in governance of the NO. At this very high level, we summarize an NO in Definition 2.

Definition 2 *An NO is best described as a tuple of ⟨Networks-profiles, Agents-profiles, Problems-profiles, Governance-profiles, Institutions-profiles⟩.*

To further specify the contents of each profile, the network profile is a graph of nodes (i.e., individuals) and links among them. Number of links will change as a result of not complete graph. Links might richly or thinly capture ties among individuals because they are most likely to be assessed when a mutual event occurs.

Definition 3 *The network profile is presented in a tuple* $\langle \vec{\mathcal{N}},\ R_{esource},\ C,\ \vec{\mathcal{F}},\ \vec{\mathcal{P}},\ \mathcal{A}_{\mathcal{U}} \rangle$.

$\mathcal{N}$ is a set of agents' profiles who are members of an NO. $R_{esource}$ is the available resources that an NO provides to the agents in order to achieve an organizational charter that is C, which includes a set of goals presented by different problems domains. $\mathcal{F}$ is a set of fitness functions for the whole NO to help in evaluating its process over time to make sure it follows a proper direction. $\mathcal{P}$ is a set of protocols to govern the activity of an NO that includes norms, rules, and roles. $\mathcal{A}_{\mathcal{U}}$ is the autonomy level of an NO, where the higher level of autonomy, the more independently the NO performs. Since the entire network might be far larger than an NO, the NO members are required to possess profiles.

Each agent will have a public profile that contains all pertinent agent attributes including their allegiances with respect to an NO, capabilities, fitness etc. to be compared with other agents. This agent's profile is presented in Definition 4.

Definition 4 *Each agent, $n_i \in \mathcal{N}$, has a profile that is a tuple of* $\langle \vec{A}_i,\ \vec{S}_i,\ R^i_{elation},\ \vec{f}_i, P_{\overrightarrow{reference}},\ A^i_{autonomy}\rangle$.

The agent i allegiance to all things it cares about is presented in A. S is a set of skills that agent i has. It includes the capacity of the agent to handle tasks. $R_{elation}$ is the agent i relations with other agents or organizations. f is the set of initial fitness values for different types of tasks based on previous experiences. $P_{reference}$ is a set of agent i preference to certain activities while limiting others. $A_{autonomy}$ is the agent's autonomy-level at which it can perform tasks independent from other agents.

Each different goal will have a different problem profile that helps in selecting best fit agents to perform certain tasks. A problem profile must contain task decomposition detail that provide task precedence and coordination requirements. Problems might have corresponding plans. When assuming that we have x number of problems and $i \in x$, problem i will have a its own problem profile presented in Definition 5.

Definition 5 *Problem profile$_{i \in x}$ is considered a tuple of* $\langle C_{ontrol},\ C_{\overrightarrow{oordination}},\ G_i,\ P_{recedence},\ I_{ndependence}\rangle$.

From Definition 5, C_{ontrol} is for controlling participants and available positions. $C_{oordination}$ is a set of coordination for each agent based on his profile for a possible assignment. G_i is the goal that the problem profile i exists to point out, which includes a set of tasks and set of plans that should be followed to achieve this goal. G also is a tuple of $\langle \vec{P_{lan}},\ \vec{IE},\ \vec{EE},\ \zeta,\ \vec{\theta}\rangle$, where P_{lan} is a set of plans needed for the G_i to be achieved. IE is the set of internal events that is a set of planned status to be achieved, and EE is the set of external events that a given NO reacts to address certain reactions based upon in order to address certain IE. ζ is the mapping function to perceive the relevance of $\forall ee_i \to ie_j$, where ee_i is the i^{th} external event of the set EE and ie_j is the j^{th} internal event of the set IE. θ is a set of tasks that agents need to handle for executing a plan, which is a set of $\{\theta_1,\ \theta_2,\ \ldots,\ \theta_m\}$, where m is the number of tasks independent from other numbers. $P_{recedence}$ is the precedence of the problem domain comparing with others (i.e., the priority level of this problem to be addressed next, must be ≤ 1, where 1 is the highest priority.) $I_{ndependence}$ stands for the independence of G_i in the problem-profile from other goals that are needed to be executed at the same time.

The governance profile includes the objectives of an NO (i.e., the organizational charters) and patterns of which those organizational charters can be achieved. It does not interfere with both agents and problem profiles, and it governs the network profile. Other possible control are inherited form other institutions that NO lives within through norm (Vázquez-Salceda, Dignum, and Dignum 2005). By the time the agents provide their profiles to the public and join an NO, they will participate in it by self-selecting a problem profile that best fits their profile and completing it. Those agents will be monitored through their NO.

Summary and Future Work

From the brief description of NO paradigm, it becomes clear that the salient properties that set NOs apart from other organizational paradigms are: (a) Openness, (b) Evolving structure, (c) Selfish allegiances and community social power, and (d) Impromptu network topology. An NO can be a small team of two or more agents working on a common, quick goal that is possibly faster than human perceptual threshold (e.g., aerial coordination at high speeds) or a large collection of agents made up of thousands of people (i.e., possibly swarms) working on long term objectives that is possibly beyond a single human's cognitive capacity (e.g., detecting climate change).

By and large, we aim to model a large variety of organizations conceptually and generically (i.e., not by an actual/empirical study). We have shown by a case study that the NO paradigm is applicable for modeling real world organizations (Alqithami, Haegele, and Hexmoor 2014). The future work will provide quantitative methods for operations in NOs that create social capital to help us guide the organization toward accomplishing its objectives; a short description is presented in (Alqithami and Hexmoor 2014b). An extended work will cover more details and applications that corroborate tenets of NOs in settings such as Net-centric warfare as well as grid-based disaster responses. Of particular interest are the potential issues arising from scaling NOs to medium and large organizations, and augmenting generic NO features with features that will be required for specific domains that are unforeseen at the moment.

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