Forces that Drive Organizational Change in an Adaptive Virtual Organization

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Abstract—Virtual Organizations are a specific type of Multi-Agent Systems that look for modeling agent organizations by means of elements typically used in Organizational Theory, such as roles, organizational goals, or services. The Organizational Theory considers that the structure of a human organization is likely to change through time, being the external and internal forces that drive organizational change the most important source for change. This work presents a set of guidelines that will help MAS designers and developers how to deal with these forces, in order to take advantage of them, or to avoid damage to the organization.

Keywords—multi-agent systems, adaptive virtual organizations, driving forces

I. INTRODUCTION

Human Organizational Theory [1] is a source of new ideas and inspiration for developing multi-agent systems. Concepts taken from this theory such as roles, services, goals, etc. and even processes for designing these kind of systems are commonly found in different proposals that try to model an Organization-Centered Multi-Agent System (OCMAS) [2] or a Virtual Organization (VO) [3]. Examples of these proposals are presented in different ways, such as agent-oriented software engineering methodologies like MOISE+ [4] or GORMAS [5], UML-like metamodels, or formal approaches like VOF [6]. All of them use their own vision for defining an organization.

However, despite these approaches represent organizational concepts, they are not ready to deal with one important requirement from human organizations, the capability of organizations to change through time. This issue has been studied by researchers from social and economical sciences like Aldrich [7] and Lewin [8]. A change in the organization is a factor that appears due to a given reason, which is known in the bibliography as forces that drive organizational change. These forces can be either internal or external, depending on where the force is coming from. A force is considered to be external when it comes from the environment of the organization (including other organizations), and internal if this force is generated by any of the elements of the organization (i.e. a change in the organizational goals or requirements). All these changes will produce a change in the organizational definition, thus modifying the organizational behavior. All the elements in the organization are eligible for being added, deleted, or modified, so organizational designers and developers must be aware of any circumstance that could produce an undesired situation in the organization. As it can be seen, these changes are generic, and specific factors for change must be defined depending on the domain of each system.

Therefore, there must exist a mechanism to help organizational managers to decide about how to act in order to face these forces that drive organizational change. There could be two possible approaches to face a force. The first one is to take advantage of it, trying to get all the positive aspects that this force could bring to the organization. On the other hand, if the force acting over the organization is bringing a negative effect on the organization it is required to try to minimize this effect. So, it is necessary to be provided with some help in order to fulfil this task.

The objective of this work is to provide a set of guidelines that help designers and developers of VOs to identify internal and external forces that drive organizational change, and also how to react to these forces, in order to take advantage or to prevent damage from them. This proposal is intended to be generical, so being possible to use it with different approaches to define VOs and OCMAS. Additionally, we want to present our definition of Adaptive VO, establishing the requirements a VO must be provided with in order to be considered as an Adaptive VO. The rest of this paper is structured as follows: Section II presents the related work on this topic. Section III describes the internal and external forces. Section IV presents the proposed guidelines to detect and face external and internal forces. Section V gives a case-study for this proposal. Finally, Section VI shows our conclusion on this paper as well as the future work.

II. DEFINITIONS AND RELATED WORK

An overview on Virtual Organizations, Adaptation, Adaptive Organizations, and Adaptation in Agent Organizations will be given to facilitate the understanding of this work.

A. Virtual Organizations

The term Organization is defined by BusinessDictionary.com as ‘a social unit of people, systematically structured and managed to meet a need or to pursue collective goals on a continuing basis. All organizations have a
management structure that determines relationships between functions and positions, and subdivides and delegates roles, responsibilities, and authority to carry out defined tasks. Organizations are open systems in that they affect and are affected by the environment beyond their boundaries.

Along with the dawn of the new era of communications where we are currently living, the concept of Virtual Organization became common in different fields, being business the first one where it appeared. BusinessDictionary.com defines Virtual Organization as ‘an organization that does not have a physical (bricks and mortar) presence but exists electronically (virtually) on the Internet, or an organization that is not constrained by the legal definition of a company, or an organization formed in an informal manner as an alliance of independent legal entities’.

DeSanctis and Monge [9] define a virtual organization as ‘a collection of geographically distributed, functionally and/or culturally diverse entities that are linked by electronic forms of communication and rely on lateral, dynamic relationships for coordination’. Despite its diffuse nature, a common identity holds the organization together in the minds of members, customers, or other constituents. The virtual organization is often described as one that is replete with external ties, managed via teams that are assembled and disassembled according to needs, and consisting of employees who are physically dispersed from one another. The result is a ‘company without walls’ that acts as a ‘collaborative network of people’ working together, regardless of location or who ‘owns’ them.

The term Virtual Organization was later used in computer science. More precisely, in one of the most trending topics in distributed computing, Grid Computing. Foster et al. [3] describe a VO as ‘a set of individuals and/or institutions defined by a sharing of computers, software, data, and other resources, as is required by a range of collaborative problem-solving and resource-brokering strategies emerging in industry, science, and engineering’.

The concept of Virtual Organization was also used in Multi-Agent Systems, where it tries to catch the essence of the concepts from business and grid computing. In this case, the ‘Virtual’ concept in Virtual Organization normally refers to its ‘virtuality’, i.e. its software existence. Thus, ‘Virtual Organization’ or ‘agent organization’ terms are usually used without distinction. Ferber [10] defined an agent organization as ‘a set of agents that interact to coordinate their behavior and often cooperate to achieve some collective goal’. Dignum [11] describes that an organization in multi-agent systems can be understood as complex entities where a multitude of agents interact, within a structured environment aiming at some global purpose. Additionally, agent organizations demand the integration of organizational and individual perspectives, the dynamic adaptation of models to organizational and environmental changes, and rely on a great extent on the notion of openness and heterogeneity of MAS. From an organizational perspective, the main function of an individual agent is the enactment of a role that contributes to the global aims of the organization. Argente [5] states that a VO is a social entity built by a set of agents that carry out different functionality, and are structured by means of a set of communication patterns and a specific topology, following a set of norms, in order to achieve the global goals of the organization.

Summarizing, we consider a Virtual Organization as a set of agents that are required to follow the structure of the organization, i.e. they have to be distributed following a given topology, they have to play a set of roles (which will state the functionalities they are able to do), and they should follow a given set of norms. Moreover, the Virtual Organization is provided with a functionality, i.e. a set of services (which are built by tasks), describing what the organization is able to do. All the entities populating the organization are required to help the organization to achieve its objectives (also known as organizational objectives).

Generally, Virtual Organizations are not considered to change their structural elements during their execution, and only a few proposals consider adaptation in VOs. That is the reason why we are interested in the study of adaptation in VOs. However, before analyzing adaptation in VOs, we need to study adaptation from a human point of view, since VOs are commonly based on human organizations.

B. Adaptation

The Merriam-Webster dictionary [12] defines adaptation as ‘the act or process of adapting, the state of being adapted’. This word has other meanings, such as ‘adjustment to environmental conditions’, ‘adjustment of a sense organ to the intensity or quality of stimulation’ or ‘a modification of an organism or its parts that makes it more fit for existence under the conditions of its environment’. Despite an organization is not a living being, this last definition is the one that best describes the objective followed when using adaptation inside an organization.

In the field of Organizational Theory [1] this concept is defined in different ways, ranging from a strategic choice, referred to the planned pursuit of ends based on a rational assessment of available means and conditions, resulting in an explicit decision to change the organization; to an environmental determinism, where environmental change is a response to environmental requirements.

Dignum [11] considers adaptation as a design factor that requires a decision, giving as a result the modification of some features of the organization. These decisions may come from two different aspects: temporality and intentionality. On the one hand, there are two types of temporal change. A temporal change is proactive when it prepares the system for an unpredictable event that can be produced in the future, and reactive if the change in the organization is carried out after a given event has occurred. On the other
hand, changes can be classified by their intentionality. In this case, the change can be offensive, if the organization wants an advantage to compete, or defensive, if the organization looks for its survival. In order to make a proactive reorganization, agents must be equipped with mechanisms that allow them to reason about and to evaluate the current organizational behavior, the desired organizational behavior, and their utility. In case of reactive reorganization, agents must be able to sense and react to environmental changes.

As a summary, adaptation is the process an organization follows in order to obtain either a benefit from an event that already happened in an organization (or from one that it is expected to occur in a lapse of time), or to avoid damage caused by an event (or to prevent damage from a future event). This event could come from the environment of the organization or from inside the organization. In order to do so, elements from the current organization must be modified (added, deleted, or changed) to face the new organizational situation. Therefore, to go deeper on the study of organizations that are able to adapt through time, the next subsection gives an overview on different definitions and approaches of adaptive organizations.

C. Adaptive Organizations

BusinessDictionary.com defines an adaptive organization as a chameleon-like organization able to keep up with the rapid changes in its environment. One of the strategies these organizations employ (to stay fast and flexible) is entrusting of more decision making powers and associated resources to their employees.

Barnett and Carroll [13] state that a change in the world of organizations occurs mainly through the adaptive responses of existing individual organizations to prior changes in technology, environment, or whatever. When an environment changes, some organizations fail and some others appear. Organizational change involves a transformation of an organization which is carried out between two points in time. An organization changes due to internal and external factors. External factors involve features related to the environment, while internal factors include, for instance, organizational changes that are applied when and how organizational managers decide, maybe following a pattern.

Aldrich [7] expresses that organizations not only react to environment changes, but also alter their structures in adaptive ways, changing goals, boundaries and activities. A transformation is a major change in an organization, involving a break with existing routines and a shift to new kinds of competencies.

Lewin [8] states that ‘an organization changes due to the action of two opposing forces, the ones that resist to change, and those that drive the organization towards a new state’.

Therefore, after studying these definitions from the business field, we can define an adaptive organization from a consensus point of view as an organization that is able to respond to changes produced either in its environment or in any of its structural elements (goals, activities, etc.). This change will be provoked by a set of internal and external forces that drive organizational change.

In the field of computer science, some definitions were also presented for adaptive organizations, focusing on adaptive OCMAS. For example, Aldewereld et al. [14] define adaptive software systems as ‘those that must have the ability to cope with changes of stakeholders’ needs, changes in the operational environment, and resource variability’.

Picard et al. [15] describe that an OCMAS is adaptive when it changes whenever its specification is not adequate, i.e. the social purpose is not being achieved and/or its structure is not adapted to the environment. This situation occurs when the environment or the MAS purposes have changed, performance requirements are not satisfied, agents are not capable of playing their roles in a suitable way or a new task arrives and the current organization cannot face it.

Dignum and Dignum [16] state that in order to keep effective, organizations must maintain a good fit with the environment. Changes in the environment lead to alterations on the effectiveness of the organization and therefore in a need to reorganize, or at least, the need to consider the consequences of the change to the organization’s effectiveness and, possibly, efficiency. On the other hand, organizations are active entities, capable not only of adapting to the environment but also of changing that environment.

As summary, it can be checked that many different definitions of Adaptive Organization in MAS have been given up to this moment. Based on these definitions, we propose a definition for Adaptive Virtual Organization, as follows:

Definition 1: An Adaptive Virtual Organization is a virtual organization that is able to modify both its structural (topology, norms, roles, etc.) and functional (services, tasks, objectives, etc.) elements in order to respond or to be ahead of changes produced in its environment, or by internal requirements, i.e. if it detects that its organizational goals are not being achieved in a satisfactory way.

Once defined what we consider to be an Adaptive VO, next subsection studies how different proposals to define agent organizations deal with adaptation concepts.

D. Adaptation in Agent Organizations

Adaptation in MAS is studied from two different points of view, depending on whether the organization is explicitly defined or not. Although our research is focused on systems where the organization is explicitly defined, it is also important to point out that there is a set of systems where the organization emerges from the interaction of the agents populating the system. These systems are known as self-organizing MAS. These systems are required to be structured, adapting themselves to a new structure if necessary; decentralized, and their components will not have a global vision of the environment, but a limited one; homogeneity
between its members, at least before the self-organization process; and their behavior must be non-deterministic [17].

However, we are more interested on the study of MAS where the organization is explicitly defined. More specifically, works carried out by Hoogendoorn et al., Dignum and Dignum, plus the ALIVE and the MOISE+ frameworks are the ones we are taking attention to.

Hoogendoorn et al. [18] presented a model for organizational change that takes inspiration from the ideas of Lewin [8], who states that a change in an organization is provoked by two opposing forces: forces that resist the change, and forces that drive towards the newly desired organization. Taking these forces into account, an organization changes following a three-phase process. First, the driving forces are stronger than forces that resist changes, thus entering in the unfreezing phase. Second, the organization enters into the movement phase, where all the needed and/or planned changes for the organization are carried out. Finally, after all changes have been deployed, the system returns to a state of equilibrium in the refreezing phase, where resistant forces are stronger than driving forces.

In order to control and carry out organizational change, a new role named Change Manager, provided with driving forces, can be added to the organization. An agent playing this role has to deal with agents playing the role Member, which will be provided with driving and resistant forces, depending on their personal opinions about change.

Dignum and Dignum [16] designed a formal semantics framework to represent an agent organization. This proposal is able to represent an organization from a static point of view, and it treats adaptation as a design issue that requires an action resulting in the modification of some organizational features, whereas other approaches are closer to the emergence of organizational patterns. Changes are represented as transitions between two different worlds, where a change in some propositions in a world can result in a different world. Reorganization consists of two activities. Firstly, the formal representation and evaluation of the current organizational state and its 'distance' to the desired state and, secondly, the formalization of reorganization strategies, that is, the purposeful change of organizational constituents (structure, agent population, objectives) in order to make a path to the possible and efficient desired state.

In this approach, a value for the organizational performance is established as a function on the environment, agents and organizational capability, and on the desired state of the affairs. Therefore, this function establishes the cost of achievement of a certain state of affairs, given the current state and group of agents. A possible strategy to decide when to reorganize says that if the cost of reorganization plus the cost of achieving the new state by the reorganized organization is less than the cost of achieving this state without reorganizing, then reorganization should be chosen.

The ALIVE project [14] is a proposal that is aimed to create a framework for software and service engineering, based on combinations of coordination and organization mechanisms (providing a flexible, high-level means to model the structure of interactions between services in the environment) and Model Driven Design (providing automated transformations from models into multiple platforms).

ALIVE is aimed to introduce mechanisms to cope with organizational change. The main sources of change in the context of an organization are the stakeholder needs, the environment conditions, and the system functionalities.

Finally, agents inside MOISE+ [4] designed systems are organized following groups. When a reorganization process starts, a set of roles (the reorganization group) is created in order to carry out with this process. For instance, there is an OrgManager role, which is in charge of managing the reorganization process, a Monitor role, which is able to monitor the organizational activity, a Historian role, which maintains history of the organization, a Designer role, with the ability of analyzing the organization, identifying the problems, and proposing alternatives, and a Selector role, which will be responsible of selecting one of the proposals from the agents playing the Designer role.

After assigning the roles from the reorganization group to agents, a reorganization scheme, featuring all the goals to follow during the adaptation process, is created. The root goal of this scheme is "reorganization", which is split into different goals, that follow the complete adaptation process: monitoring, design, selection, and implementation.

Summarizing, it can be stated that all the presented proposals represent a good approach to deal with adaptation in agent organizations. Some of them take inspiration from the Organization Theory. For example, the proposal from Hoogendoorn takes into account the existence of forces that drive organizational change. However, none of these proposals specifies neither the set of different forces that drive organizational change nor the guidelines specifying how to detect and face them. Therefore, in this paper we will first give an overview on the forces that drive organizational change in Section III, and then a set guidelines to help detecting and facing these forces is presented in Section IV.

III. Forces That Drive Organizational Change

An organizational change is produced by one or some forces that can be differentiated by their nature. Some organizations are more vulnerable than others to the pressure of change, such as organizations with diffuse objectives, uncertain support, unstable values and those that face a declining market for their products and services. These forces can be classified into two groups depending on their origin: external and internal. Next subsections describe some of the most relevant forces that drive organizational change.

A. External Forces

The external forces [7] are those that promote change inside an organization due to changes in its environment.
Thus, they are referred to the environment where the organization is located, and are due to elements such as other organizations that populate the same environment (and some of them could suppose competence) or the different heterogeneous agents in the same environment. Among external forces, the following forces can be found: (i) Obtaining resources: a failure when obtaining resources (e.g. because they are no longer reachable from the current environment) could drive the organization to improve the way in which resources are obtained; (ii) Market forces: requirements of products and services of an organization may change through time. Therefore, organizations that offer services or products that nobody is requiring have no reason to exist, so they will disappear if they do not decide to change; (iii) Generalization: an organization can adopt new technology in order to improve its productivity inside the market where it is operating; (vi) Competence: organizations with a similar purpose (e.g. offering similar products and services, or looking to achieve similar goals) in the same environment turn into competence for them; (vii) Demographical features: since organizations are open systems, agents populating them and their environment are heterogeneous. An organization must control this diversity in an effective way, paying attention to the different needs of these agents, but trying to avoid malicious and/or interested behaviors by them; (viii) Laws and regulations: not only internal regulations are important for an organization. There can be also external laws coming from the environment that could affect the behavior of the organization; (ix) Globalization: globalization refers to the increasing unification of the world’s economic order through reduction of barriers to international trade as tariffs, export fees, and import quotas.

B. Internal Forces

The internal forces [7] of an organization are signals produced inside an organization, indicating that a change is necessary. Thus, it is important to clearly define these forces, in order to monitor them and to achieve the change in the most appropriate form and moment. The internal forces are: (i) Growth: when an organization grows in either number of members or budget, it is necessary to change its structure to a more hierarchical organization, with higher levels of bureaucratization and differentiation among its members; (ii) Power and political factors: members in highest levels of the hierarchy may have different goals than agents in a lower hierarchical level, and can be even different from the organizational goals. The organization may assure (e.g. by means of observers) that managers do not impose their goals above the organizational ones; (iii) Goal succession: after reaching their goals, an organization could disappear. If it wants to continue with its existence, new goals need to be chosen; (iv) Life-cycle: some existing organizations follow the classic life-cycle model. Thus, they appear, grow, change, and disappear, to give way to other organizations; (v) Human resources: managers of the organization must control that their agents are committed with the organization, present an adequate behavior and their performance is acceptable regarding organizational goals; (vi) Decisions and managers behavior: disputes between agents and their supervisors inside organizations can lead to subordinates asking for new tasks and roles; (vii) Economical restrictions: organizations want to maximize their performance, trying to obtain maximum benefits using the less possible amount of resources. If too much resources are being consumed, a change can be necessary; (viii) Merging and acquisitions of organizations: merging of organizations, or the acquisition of one organization by another, leads to bigger organizations where their structure and members should be reorganized; (ix) Crisis: if an organization is in a crisis due to a sudden drop of its efficiency, a possible solution is a deep organizational change, modifying structural and/or functional elements, depending on its specific needs.

IV. IDENTIFYING AND FACING FORCES THAT DRIVE ORGANIZATIONAL CHANGE

In the previous section we have described the forces that drive organizational change from a human point of view. For the OCMAS field, it is necessary to provide a set of guidelines that could help designers and developers on how to identify when an external or internal force is acting over the organization. Following, we propose a guideline for identifying and facing forces that drive organizational change in an adaptive VO. In this guideline each force is presented by means of the factors that help to state whether the force is currently acting or not. This solution can be either related to how to take advantage of the benefits the force could bring to the organization or related on how to minimize the possible damage that the organization could suffer after the appearance of the force.

It should be noticed that, even if we develop in this paper an example on our proposal by means of a specific work to define VOs, these guidelines expect to be generic, thus being able to be used along with any existing definition of OCMAS.

A. How to Identify when a Force is Acting

A key issue when dealing with adaptation is that forces that drive organizational change should be correctly de-
tected. We have defined a template (Table I) of guidelines for detecting when a force is acting over the organization.

For each common force that drives organizational change, a guideline has been completed by instantiating this template. On each of these guidelines, there are represented the different factors that should be monitored in order to detect that a force is acting. It must be noted that not all factors are required to be detected in order to state that a specific force is acting over an organization, but just a subset of these factors could be able to trigger a force. Moreover, it is possible for each factor to come from different sources. For example, from the behavior of an agent, or the level of achievement of a goal or set of goals.

Table I

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Name of the force to be detected with this guideline</td>
</tr>
<tr>
<td>Description</td>
<td>Description of how the force acts over an organization</td>
</tr>
<tr>
<td>Type</td>
<td>Internal or external</td>
</tr>
</tbody>
</table>

B. Facing the Force

We have defined a guideline (Table III) for identifying the different organizational actions that should be carried out in the organization in order to take advantage or to prevent damage from a specific force.

Each solution is described by means of its name, its description, the force (or forces) that are intended to take advantage of or trying to reduce its damaging effects over the organization. Also, this guideline points out the factors for detecting a force that must appear along with the force in order to be possible to apply this solution, as well as the specific roles that will carry out this solution, and the organizational actions that will produce a change in the definition of a VO when they are executed.

Table III

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Name</td>
<td>Name of the solution</td>
</tr>
<tr>
<td>Description</td>
<td>Text describing this solution</td>
</tr>
<tr>
<td>Force</td>
<td>The force that must be acting to apply this solution</td>
</tr>
<tr>
<td>Factor</td>
<td>The factors that must be detected in order to apply this solution</td>
</tr>
<tr>
<td>Actions</td>
<td>The set of actions that must be carried out to apply this solution</td>
</tr>
<tr>
<td>Roles</td>
<td>The responsible roles for applying this solution</td>
</tr>
</tbody>
</table>

As an example on how these guidelines are instantiated, we depict here the Obtaining resources force. Resources are commonly used as raw materials to produce the results of the services of an organization. Therefore, if a service is called, and it has a precondition that specifies that a resource is needed to execute a service, but the resource cannot be obtained using the current organizational structure, it is necessary to look for a solution.

Table II gives the guidelines about how to detect this force, including the factor that will be necessary to control in order to state that this force is acting over the organization.

Table II

<table>
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<tr>
<th>Field</th>
<th>Description</th>
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<tbody>
<tr>
<td>Name</td>
<td>The name of the factor that helps identifying the force</td>
</tr>
<tr>
<td>Description</td>
<td>The description of this factor</td>
</tr>
<tr>
<td>Type</td>
<td>The type of the factor (e.g., behavior, goal achievement, etc.)</td>
</tr>
<tr>
<td>Value</td>
<td>The value that this element must reach/not reach in order to be considered as a factor for change</td>
</tr>
<tr>
<td>Triggers</td>
<td>Specifies whether this factor triggers the force by itself, or other factors are required by a force to start acting over an organization</td>
</tr>
</tbody>
</table>

Guideline for detecting a driving force

Detection of "Obtaining resources" external force

As an example on how these guidelines are instantiated, we depict here the Obtaining resources force. Resources are commonly used as raw materials to produce the results of the services of an organization. Therefore, if a service is called, and it has a precondition that specifies that a resource is needed to execute a service, but the resource cannot be obtained using the current organizational structure, it is necessary to look for a solution.

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</tr>
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<td>Roles</td>
<td>The responsible roles for applying this solution</td>
</tr>
</tbody>
</table>

A possible solution to the "Obtaining resources" force (Table IV) is to admit an external agent (coming from the environment or from another organization) to join the organization. This agent must be able to get the requested resource and to bring it to the organization.

Table IV

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Add agent to the organization</td>
</tr>
<tr>
<td>Description</td>
<td>A new agent joins the organization to bring the needed resource</td>
</tr>
<tr>
<td>Force</td>
<td>Obtaining resources</td>
</tr>
<tr>
<td>Factor</td>
<td>Threshold of successfully executing a service</td>
</tr>
<tr>
<td>Actions</td>
<td>Register agent</td>
</tr>
<tr>
<td>Roles</td>
<td>Organizational manager</td>
</tr>
</tbody>
</table>

V. USING GUIDELINES TO DESIGN ADAPTIVE VO

In this section, we will study the situation of a company that could be modeled as an Adaptive Virtual Organization. Therefore, we present an overview of the company and then we will depict how a force could be detected and faced by the organization.

Our example here is the ACME company, which is a family business owned by John and Jane Doe, a couple from Springfield, USA. It manufactures computer processors, and although competence is high, they have signed some important contracts with retailers and computer manufacturers around the world to sell them ACME-branded products. At the top of the organizational hierarchy is Jane, which is the President of ACME (i.e., she is playing the role President), while John is playing the CEO role. After them, Alice, the daughter of the couple, is the supervisor of the marketing department of the company, while Bob (Alice’s brother) holds the manager role in the manufacturing department. In lower levels of the hierarchy there are other intermediate managers and supervisors, as well as subordinated agents. This company has been modeled using the Virtual Organization Formalization (VOF) [6], which is aimed to identify...
the elements that compose a VO, providing a formalization as much complete as possible, facilitating the adaptation process, and checking its correctness.

We present here the definition of a VO using VOF. Details for deeper levels of the formalization can be found in [6].

Definition 2: A Virtual Organization \( vO \) is defined, at a given time \( t \), as a tuple \( vO(t) = (OS(vO(t)), OE(vO(t)), \phi(vO(t))) \) where:

- \( OS(vO,t) \) refers to the Organizational Specification of \( vO \), which describes the structural definition of the organization, at a given time \( t \). It is defined as \( OS(vO,t) = ⟨SD(vO,t), FD(vO,t), ED(vO,t), ND(vO,t)⟩ \) where:
  - \( SD(vO,t) \) is the Structural Dimension of \( vO \) at a time \( t \). It defines roles and relations between them.
  - \( FD(vO,t) \) is the Functional Dimension of \( vO \) at a given time \( t \). It describes the functionalities of the system, including goals, services and tasks.
  - \( ED(vO,t) \) is the Environment Dimension of \( vO \) at a time \( t \), which describes the environment of the organization, including artifacts and workspaces.
  - \( ND(vO,t) \) is the Normative Dimension of \( vO \) at a given time \( t \), defining the norms that rule a VO.

- \( OE(vO,t) \) refers to the Organizational Entity of \( vO \) at a given time \( t \), which represents the entities populating the system, which can be agents or other VOs.

- \( \phi(vO,t) \) refers to the Organizational Dynamics of \( vO \) at a given time \( t \), allowing to relate \( OS(vO,t) \) with \( OE(vO,t) \). It has information about role allocation and active norms and services.

In this paper, due to the lack of space, we will include a simplified definition of ACME. Note that if there are elements not depicted in this description is not because they do not exist, but they are not relevant for this example. Therefore, the ACME company is defined with VOF as:

\[ vO(t) = (OS(vO(t)), OE(vO(t)), \phi(vO(t))) \]

where:

- \( OS(vO,t) = ⟨SD(vO,t), FD(vO,t), ED(vO,t), ND(vO,t)⟩ \), where:
  - \( SD(vO,t) = \{ R, Rel \} \), and R = \{ President, CEO, Manager \} is the set of roles
  - \( FD(vO,t) = \langle G.S.GoalDep \rangle \), where \( G = \langle \text{MaximizeProfit}, \text{MakeProcessors} \rangle \) is the set of goals, and \( S = \langle \text{MakeProcessors}, \text{Sell} \rangle \) is the set of services
  - \( ED(vO,t) = \langle WSO, AR, EnvFunc \rangle \), where \( WSO = \langle w_{1} \rangle \) is the set of workspaces the VO perceives, and \( AR = \langle \text{silicon} \rangle \) is the resource the VO perceives
- \( OE(vO,t) = \langle John, Jane, Alice, Bob \rangle \) are the entities (agents) populating the VO
- \( \phi(vO,t) = \langle play, Pop \rangle \), where:
  - \( play = \{ \{ Jane \rightarrow \text{President} \}, \{ John \rightarrow \text{CEO} \}, \{ Alice \rightarrow \text{Manager} \}, \{ Bob \rightarrow \text{Manager} \} \) shows the roles each agent is playing

\[ Pop = \langle w_{1} \rightarrow \{ John, Jane, Alice, Bob \} \rangle \]

which agents are populating each workspace.

A. Identifying when a Force is Acting

In this paper, we depicted the example of the ‘Obtaining resources’ force, which could be correctly detected by means of the guideline in Table II. This force is possible to affect ACME in the case this company is not able to get silicon to manufacture processors. When ACME wants to manufacture new processors, the service Manufacture is called, which fails if the service is not able to get the required silicon.

The ‘Obtaining resource’ force is acting over an organization (from a period of time between \( n \) and \( n + m \)) if this equation holds:

\[
\sum_{n-m}^{n+m} \text{achievedPrec}(s_{1}, ar_{1}) < \text{threshold} \tag{1}
\]

where:

- \( \text{achievedPrec} : S \times AR \rightarrow \{0, 1\} \) indicates if a service \( s_{1} \in S \) requires a specific resource \( ar_{1} \in AR \)
- \( \text{calls} : S \times T \times T \rightarrow \mathbb{N} \) is a function that indicates the number of times a service \( s_{1} \in S \) has been called during a frame of time \( n, n + m \in T \).

In this example, the threshold was established to 0.5. The number of calls to the service Manufacture during the studied time lapse (i.e. \( \text{calls}(\text{Manufacture}, t_{1}, t_{2}) = 6 \)), while the function \( \text{achievePrec}(\text{Silicon}, \text{Manufacture}) \) returned 2 as the sum of all its executions during this time lapse. Therefore, we can state that this force is acting over ACME. Thus, a solution for this force must be carried out.

B. Facing the Force

Once the force has been detected to be acting over the organization, it is then necessary to face it, trying to get benefit from it or to avoid damage the force could produce, by following the guideline in Table IV. It consists on accepting an external agent into the organization which should be able to bring the desired resource to the organization.

Therefore, an external agent named Claire, which should provide ACME with the required amount of silicon, is accepted to join the organization. In order to do so, it is necessary to ‘move’ the agent Claire to ACME, by adding her to the list of agents of the organization, and also to one of the workspaces of the organization. As previously stated, the proposed guideline for each force is generic, so extra changes to the organization can be carried out if it is considered as required or beneficial for the organization. In the ACME example, since Claire is playing a new role in the organization (which is named as Provider) it is necessary to modify the list of organizational roles. Additionally, a new service GetSilicon is defined so as to request Claire more silicon to manufacture processors.
Therefore, the new organizational definition after this adaptation process is:
\[ \text{vo}(t+1) = \langle OS(\text{vo},t+1), OE(\text{vo},t+1), \Phi(\text{vo},t+1) \rangle, \]
where:

- \[ OS(\text{vo},t+1) = \langle SD(\text{vo},t+1), FD(\text{vo},t+1), ED(\text{vo},t+1), ND(\text{vo},t+1) \rangle, \]
- \[ SD(\text{vo},t+1) = \langle R', Rel \rangle, \text{ and } R' = \langle \text{President, CEO, Manager, Provider} \rangle \]
- \[ FD(\text{vo},t+1) = \langle G, S', GoalDep \rangle, \text{ where } G = \langle \text{MaximizeProfit, MakeProcessors} \rangle, \text{ and } S = \langle \text{GetSilicon, Manufacture, Sell} \rangle \]
- \[ ED(\text{vo},t+1) = \langle WSO, AR, EnvFunc \rangle, \text{ where } WSO = \langle W_3 \rangle, \text{ and } AR = \langle \text{silicon} \rangle \]
- \[ OE(\text{vo},t+1) = \langle \text{John, Jane, Alice, Bob, Claire} \rangle \]
- \[ \Phi(\text{vo},t+1) = \langle \text{play}', Pop' \rangle, \text{ where:} \]
  - \[ \text{play}' = \langle \{ \text{Jane} \rightarrow \text{President} \}, \{ \text{John} \rightarrow \text{CEO} \}, \{ \text{Alice} \rightarrow \text{Manager} \}, \{ \text{Bob} \rightarrow \text{Manager} \}, \{ \text{Claire} \rightarrow \text{Provider} \} \rangle \]
  - \[ \text{Pop'} = \langle \text{W}_3 \rightarrow \langle \text{John, Jane, Alice, Bob, Claire} \rangle \rangle \]

VI. CONCLUSIONS AND FUTURE WORK

This paper presented a set of guidelines aimed to deal with forces that drive organizational change, which are external or internal depending on their origin. The first guideline helps identifying the force, enumerating the different factors that must occur in the organization and/or in its environment in order to state that the given force is acting. The second guideline helps organizational managers on how to face each force, trying to get positive effects that will help the organization, and trying to avoid negative effects that could damage the organization. These solutions are a set of organizational actions, which are those that provoke a change in the organizational structure. It must be noted that both guidelines are presented in a generic way, so organizational designers have to adapt them to their specific domain. However, we used the Virtual Organization Formalization (VOF) to illustrate an example on the presented guidelines. Forces we are considering are those established by Organizational Theory researchers as the most common ones. Most of these forces are able to be moved into the MAS domain. These guidelines are intended to be general and to be used with any Organization Oriented definition of a MAS. As future work, we plan to use our proposed guidelines to enhance the GORMAS methodology [5], so as make it able to define not only VOs, but Adaptive VOs.

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