Establishment of Collaborative Networks – A Model-Driven Engineering Approach Based on Thermodynamics

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Abstract. The setup of an efficient collaborative situation between organizations can be considered according to four main complementary dimensions: the *context* (geographical, social, economical environment), the *partners* (the actors, their capabilities, their resources and their relationships), the *objectives* (the collaborative goals of the network, the risks to be avoided, etc.) and finally the *behaviour* (the collaborative processes to be implemented by the *partners* to achieve the *objectives* considering the *context*). Some research works try to infer the *behaviour* based on the three other issues assumed to be known, by using different approaches such as model-driven engineering (MDE), optimization, heuristics, planning, etc. MDE helps studying the opportunity of inferring the *objectives* part from the *context* and *partners* dimensions in order to feed the *behaviour* issue. We use a non-equilibrium thermodynamics analogy where *partners* and *context* attributes and methods are mapped to thermodynamic state variables of an organisation seen as an open system in the frame of dissipative structure thermodynamics. We apply it specifically to enterprises and discuss briefly the analogy of *behaviour* as an irreversible trajectory aiming to maintain the enterprise activity alive.

Keywords: collaborative network, thermodynamics, metamodel, model-driven engineering, knowledge management.

1 Introduction

The starting point of this article is quite simple: *Would one be able to know some state variables of a set of atoms (about their structure, energy, etc.) and about the environment of these atoms (pressure, temperature, etc.), one can infer the way these atoms will self-organize and self-structure within the next periods of time*. Could we reasonably think about having the same kind of approach for organizations? Is there any chance to characterize organizations, their ecosystems and their kinetics in a way that would allow us to define laws and rules to predict or infer the evolution and structure of networks of organizations? Is that a fantasy to try to find state variables and evolution laws for extended enterprises and collaborative networks?

This article focuses on both these dimensions: state variables and laws. Consequently, this article is structured in two main parts. The first one (section 2) presents a theoretical framework to model collaborative networks of organizations according to four dimensions: the *context* (geographical, social, economical environment), the *partners* (the actors, their capabilities, their resources and their relationships), the *objectives* (the collaborative goals of the network, the risks to be avoided, etc.) and finally the *behaviour* (the collaborative processes to be implemented by the *partners* to achieve the *objectives* considering the *context*). The second one (section 3) describes principles to deal with models and define rules and mechanisms that could exploit those models to support the design of efficient and relevant collaborative networks. Basically, the idea is to use *context* and *partners* models to create *objective* models. These three points of views (*context*, *partners* and *objective*) could then be used in a model-driven engineering approach to build the fourth one; *behaviour* point of view.

2 Modelling Framework for Collaborative Situations

The characterization of a collaborative situation requires describing several points of view. To describe clearly these points of view, this article directly refers to system modelling (as far as a network of organizations can be considered as a system, or a system of systems) and to enterprise modelling (as far as organizations may be considered as enterprises from a modelling perspective). On the one hand, system modelling is traditionally based on three main dimensions [1]:

- *Requirement/Functional view*[1]: This dimension describes mainly the expectations of the system. It is dedicated to clarify its purposes.
- *Structural view*: This dimension presents on the one hand the components of the system and the relations they have with each other, and on the other hand the environment of the system and the relationships between the system (its components) and that environment.
- *Behavioural view*: This dimension describes the dynamic aspect of the system and the way it performs. It is dedicated to model the processes and the performances of the system.

Enterprise modelling, on the other hand, is often considered according to four points of view [2]:

- Informational view: This point of view describes the embedded data and associated knowledge of the organization.
- Functional view: This point of view presents the whole capability of the organization through its behaviour and its processes.
- Organizational view: This point of view describes the responsibilities, allocations and hierarchical schemes of the structure of the organization.
- Resources view: This point of view presents the means and the individual capabilities of people, software, machines composing the organization.

[1] The name can be different (*e.g.* in SysML formalism or in System Engineering domain)

Considering that the main objective of setting up a collaborative network can be seen as "*the design of an organization, which is a system of organizations*" the previously described points of views (about system modelling and enterprise / organization modelling) should be considered to define the modelling framework of collaborative situations.

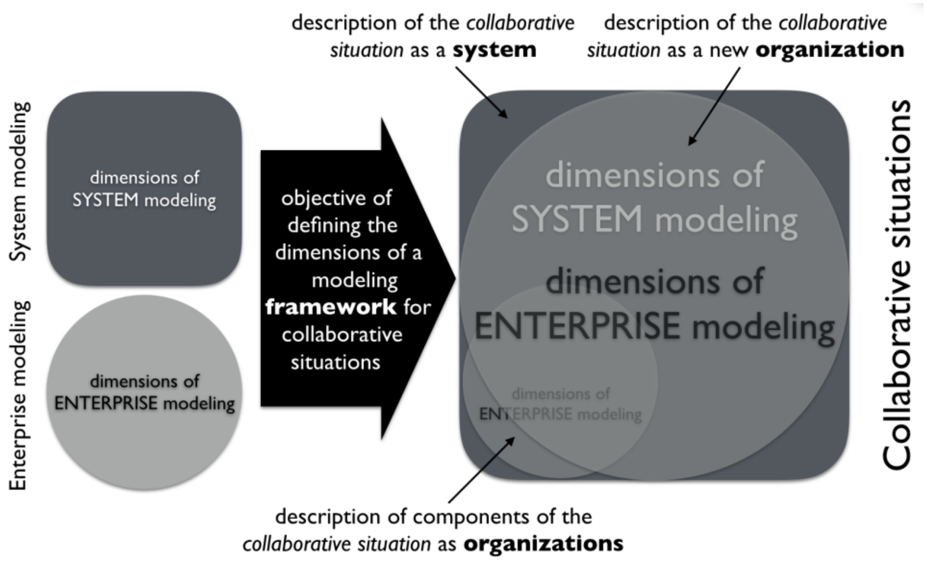

Fig. 1. The use of *enterprise* and *system* modelling dimensions with regards to the objective of defining the modelling dimensions of a *collaborative situation* framework.

Based on the overall idea presented in figure 1, the main challenge is to exploit the modelling dimensions inherited from Enterprise/System modelling framework to create the appropriate modelling framework (and its relevant points of view) for collaborative situations.

The basic principles to reach that objective are the following:

1. The collaborative situation modelling framework should be based on the system modelling dimensions (*because the collaborative situation is a system*).
2. Considering the way the collaborative situation should be integrated in its environment, the structural view of the framework could be split in two parts: components (*i.e.* partners) and environment of the network.
3. A collaborative situation model should embed knowledge about information, functions, resources and organisation of the network as a whole (*because the collaborative situation is an organization*).
4. The dimension (of the collaborative situation modelling framework) specifically describing components (*i.e.* partners) should be based on the enterprise modelling dimensions (*because partners are enterprises*).

Figure 2 presents the consequences of these principles on the basis of the big picture presented on figure 1.

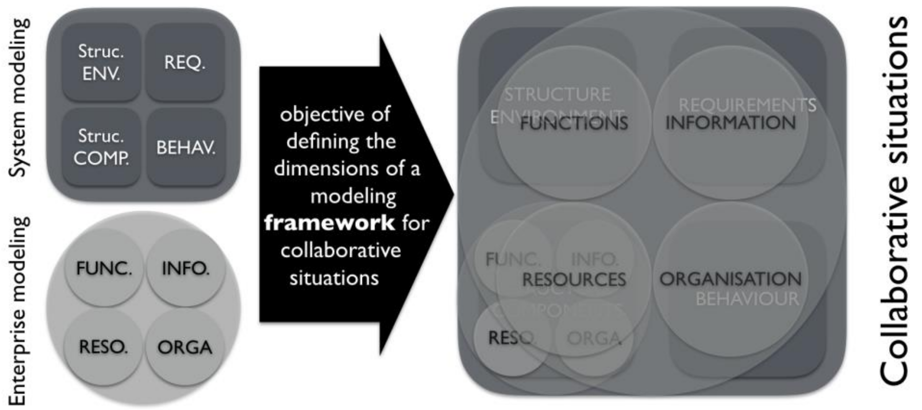

Fig. 2. The mapping principle of *enterprise* and *system* modelling dimensions on the modelling dimensions of a *collaborative situation* framework.

From figure 2 and the previously listed principles, it is possible to legitimate that the collaborative situation modelling framework presented in this article is structure according to four main dimensions: (i) *context* (*i.e.* "structure environment" from figure 2), (ii) *partners* (*i.e.* "structure components" from figure 2), (iii) *objectives* (*i.e.* "requirements" from figure 2) and (iv) *behaviour* (*i.e.* "behaviour" from figure 2). Besides, the *partner* dimension should include concepts describing *information*, *functions*, *resources* and *organization* of the involved or available partners. Furthermore, the four mentioned dimensions for the whole framework (*context*, *objectives*, *partners* and *behaviour*) should include as well concepts describing *information*, *functions*, *resources* and *organization* of the collaborative network.

Consequently, the framework (Figure 3) proposed in this article is the following:

- *Context dimension* (light grey) including components and characteristics of the considered environment, and also opportunities or threats specific to these environment characteristics.
- *Partner dimension* (strong grey) expresses the different resources and know-how of the partners. This includes notably capabilities, patterns, instructions, resources (information, material, people, etc.), flows (linking capabilities) and connector / mediator able to orchestrate the different business processes.
- *Objective dimension* (medium grey) containing characteristics of collaborative network (common objective and facts that the collaboration has to manage).
- *Behaviour dimension* (dark grey) that characterized the concrete operations, which are deployed to concretize the collaboration. This includes business processes / activities and their associated events and messages. Besides, this dimension includes as well a *Performance point of view* (white) that assesses the overall performance of the collaboration by comparing, through dedicated Key Performance Indicators (KPIs), the performance objective to the measures on the field.

Figure 3 presents the modelling framework for collaborative situations with the four aforementioned dimensions embedding concepts and relations between concepts to describe a collaborative situation (whatever the concerned business domain).

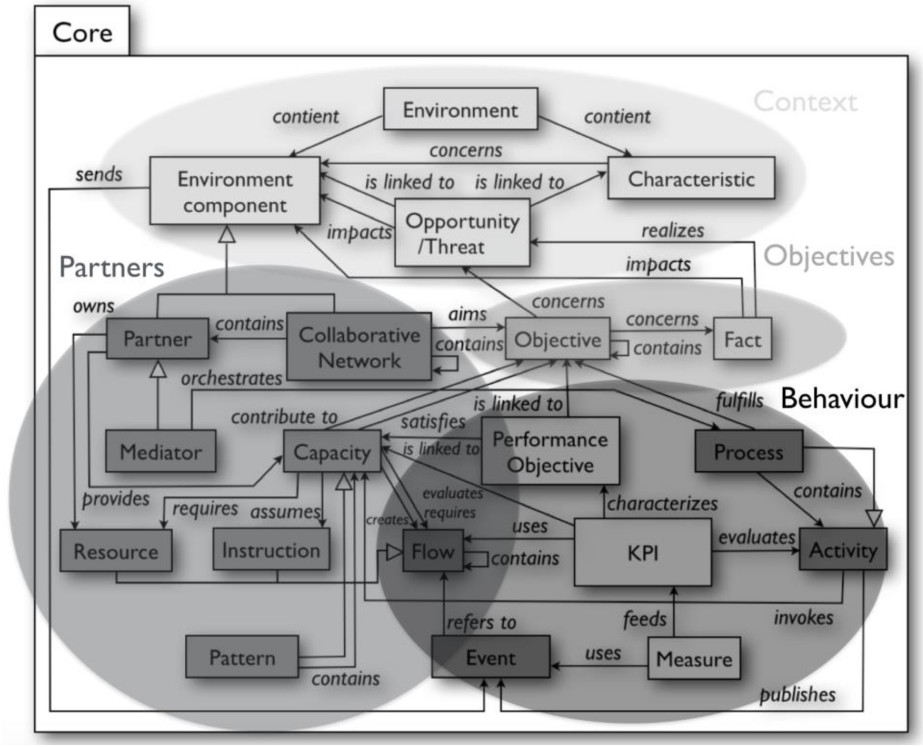

Fig. 3. *Concepts* and *relationships* between concepts embedded in the four-dimension framework of collaborative situation modelling (from [3]).

Based on the previous statements, this article claims that a collaborative situation may be modelled by instantiating *concepts* and *relations* of the previous diagram presented in figure 3, which is actually a *collaborative situation metamodel*. The next question at this point is "*how can such a collaborative situation model be used to infer the way a collaborative situation could be established, could evolve and even catch opportunities or re-organize to remain successful?*" and more precisely: "*is it possible to model part of the collaborative situation (e.g. partners and context) and infer the other part?*". This is a direct echo to the question asked in the introduction of this article: considering the characteristics of a set of organizations (partners) and the characteristics of the environment they are involved in (context), is it possible to define what could be done by such a group of organizations in that environment (objectives) and how should this network of partners perform (behaviour).

3 Designing and Implementing Collaborative Situations

The initial question (introduction) was: "*Is there any chance to characterize organizations, their ecosystems and their kinetics in a way that would allow us to define laws and rules to predict or infer the evolution and structure of networks of organizations?*". From the conclusion of section 2, the resulting purpose is to partially model a collaborative situation in order to infer the complementary part of the model. Obviously, from section 2 only, there is no indication about what part could be modelled and what part could be inferred. There is huge combinatory coverage of sub-sets of one, two or three dimension models to be done to deduce the three, two or one missing dimension models. For instance, the objective could be to model *partners* and *objectives* (who and what) to try to infer *context* and *behaviour* (where and how). But there are actually fourteen options (four options with three modelled dimensions, six options with two and finally four with one modelled dimension).

However, from the initial question and the analogy with atoms or molecules, the objective is definitely more precise: from the model of a set of organizations (partners) and of the environment they are involved in (context), the purpose is to define what could be done by such a group of organizations in that environment (objectives) and how should this network of partners perform (behaviour).

Actually, previous research works ([4], [5]) use model transformation through knowledge bases (ontologies for some application domains and graph data bases for some others) to automatically infer *behaviour* models from *context*, *partners* and *objectives* models. Based on stakes and characteristics of the *context*, capabilities of *partners*, goals to reach and risks to avoid from *objectives*, model transformation rules automatically build collaborative business process models in BPMN-like format. These contributions are our starting point and show that it is possible to infer *behaviour* from *context*, *partners* and *objectives*. But we feel reasonable to go a step further by attempting to get the *objectives* model from the *context* and *partners*' dimensions and then thanks to [4] and [5], infer the *behaviour* model.

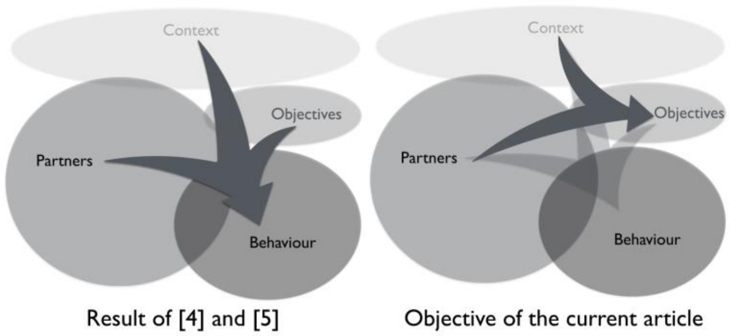

Fig. 4. The use of existing results to support the objective of the current article.

Basically, this objective is trying to get "what" can a group of partners make altogether considering their own characteristics and their environment, and finally, "how" could they reach these objectives. From [6], "a *collaborative network* (CN) is constituted by a variety of entities (e.g., organizations and people) that are largely autonomous, geographically distributed, and heterogeneous in terms of their: operating environment, culture, social capital, and goals”. This definition strongly highlights three main features: (i) autonomy of partners, (ii) distribution of partners and (iii) heterogeneity of partners.

We now focus on an enterprise seen as an organisation and carry on with a non-equilibrium thermodynamic (NET) analogy. The second law of Thermodynamic states that closed systems evolve to maximize their entropy, reaching the equilibrium state, often referred as a dead state. Instead, we consider the enterprise as open system, developing in the so-called the *context* (see section 2). We can further define the *context* by three state variables: *opening* (presence of strong competitors / demanding partners and suitable informational / physical connections between them), *easiness* (favourable legal, cultural and financial frame) and *wideness* (expanse of the environment). They can be assigned respectively to the thermodynamic *temperature T* (ability to move), *pressure P* (constraint to a move) and *volume V* (figure 5). As is usual, an equation of state can relate *P* easiness, *T* opening and *V* wideness, like the Virial Equation of state: $PV/(n\mathrm{R}T) = 1+\mathrm{B}(n/V)+\mathrm{C}(n/V)^2\ldots$ R is the ideal gas constant and N is the number of potential partners. 1 is the ideal gas contribution (no partner interaction) whereas B (C) is the second (third) virial coefficient accounting for two (three) partners interactions. Notice that *easiness* and *opening* can be obtained from the metamodel (figure 3) respectively as (i) the number and the nature of *environment components*, together with some of the *characteristics* of the environment and (ii) *opportunity* and *threat*, together with some of the *characteristics* of the environment.

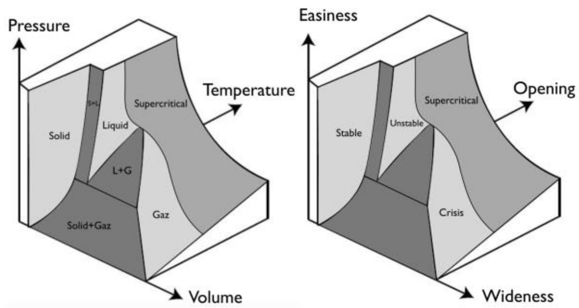

Fig. 5. Thermodynamics analogy for the context of collaborative situation.

According to NET, open systems are subjected to forces that counter gradients: e.g. heat flows from high to low temperature so as to make temperature uniform at the equilibrium state. We postulate that the enterprise lies in a non-equilibrium stationary state as forces and gradient may be balanced over time in the enterprise *context*. Being out of equilibrium, its internal entropy is lower than the equilibrium maximal entropy and that entropy decrease ΔS can be interpreted in two ways: i) it increases the system free energy $\Delta A=\Delta U-T\Delta S$. A is assimilated to the ability to perform work and U describes the enterprise assets [7], ii) as a degree of internal organisation. This later meaning could be discussed further by using extremal principles under external constraints, like Bejan’s constructal law or thermodynamics’ MaxEP [8].

The enterprise *behaviour* translates into a trajectory from its present state to a new one within a modified *context*. Such a trajectory is not reversible, since its duration would be infinite according to thermodynamics fluctuation theorems, which deal with the success probability of a trajectory [7]. Hence, the activity generated through the trajectory is irreversible and in compliance with the 2^{nd} law, it induces a dissipation, comparable to heat, consecutive to the activity's work. We also postulate that the enterprise decision to move to another state is driven by the information gathered by the enterprise, including all the constraints narrowing the path. Then it is processed as *objectives* in order to initiate a *behaviour* that ensures the enterprise's survival.

4 Conclusion

The current article tries to make the link between an approach for modelling collaborative situations based on a metamodel covering the four main dimensions of such a system of organizations and scientific domains such as thermodynamics and chemistry. The ultimate goal of these emerging considerations is about the way to characterize the *context* and the *partners* of a collaborative situation with regards to state variables and characteristics of atoms and molecules. This article is a tentative first step into this field. The expected benefit would be a modelling environment where organizations and their context could be characterized and the obtained models could be constantly updated. Based on the laws and rules inherited from chemistry and thermodynamics, the system could provide the organizations with decision support regarding the collaborative networks they could join or create.

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