Towards a Model of Organisational Rules in Complex Adaptive Systems

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Abstract

Organisational rules, which guide and constrain enterprise agents' actions, are essential to maintaining structure and coherence in dynamic environments. However, these rules often exist in complex and interconnected networks, leading to ambiguity, contradictions, and lack of comprehensibility. By applying Complex Adaptive Systems (CAS) theory, this research develops a conceptual model of rules to understand the multi-level interactions between organisational agents and the constraints that influence their behaviour. In addition to organisational agents and rules and their interconnections, the model represents concepts from complexity theory, as well as emergent properties, feedback loops, and adaptation. Future work will iterate on this model, incorporating practitioner insights to refine the concepts and identify relevant elements for a modelling language for systems of organisational rules.

Keywords

conceptual model, meta-model, enterprise modelling, organisational rule, complex adaptive system, legal design

1. Introduction

This section discusses the concepts used in this article's title, and also describes how the study fits into an ongoing research project.

1.1. Organisational Rules

An essential component of any enterprise is its organisational rules, which may be developed internally or imposed by external factors. These rules guide and constrain employees' actions within the organisation. Making informed decisions modifying these rules is also critical for organisational development [1]. However, engaging with rules is not straightforward. The rules themselves and the complex organisational contexts they aim to govern can often be ambiguous, contradictory, and difficult to comprehend. For example, in the Swedish healthcare sector, even experts find it challenging to fully grasp the regulations around privacy and digital transformation [2, 3]. This creates significant uncertainty, reduced interoperability, and missed opportunities for collaboration.

In this paper, as in a previous study [4], we define an organisational rule as a formal element that constrains the decision space of an organisational unit, applying to a wider business context rather than IT systems. Such rules are formalised, meaning they are documented and officially recognised within the organisation. They may originate internally or externally, ranging from strictly enforced rules to mere guidelines.

1.2. Complex Adaptive Systems

Organisations and their rules are socio-technical systems that can be comprehended through systems theory. As the complexity of organisational reality increases, scholars argue that enterprises should be understood through the lens of complex adaptive systems (CAS) theory [5, 6].

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CAS theory can be described as the intersection between general systems theory and complexity sciences [6]. Complexity sciences emphasise that the world is messy [7], fuzzy [8], non-linear [6], and non-deterministic [6].

A CAS consists of two key elements: agents and constraints, including their interconnections. The boundaries between systems are fuzzy, and agents are often interconnected to agents in other systems. Like any structure, the composition of these elements gives rise to emergent properties. Some emergent properties are possible to foresee, but others are not. According to their constraints, agents interact [6] with other agents in their environment [9]. Interactions influence events that over time form behaviour at both local and higher levels [10]. In some cases, emergent behaviours stabilise into new, higher-level agents [11]. In these multi-level systems [12], complex agents can be viewed both as agents and as systems composed of lower-level agents and their constraints. Agents learn from the results through feedback loops [10] and adapt [13] accordingly by modifying the constraints.

From a CAS theory perspective, there is often reason to be sceptical about efforts to in detail control a system from above with strict rules or precisely predict possible futures and situations. In a management context, it becomes more relevant to make simple and flexible rules, work in iterations, design effective feedback loops, and make careful adjustments.

CAS theory is particularly prominent in healthcare management [13, 14, 15, 16], especially in fostering organisational collaboration [17]. Organisational collaboration is considered to have great potential to improve outcomes in sectors such as healthcare [17], but can also be demanding and have many unforeseen consequences.

1.3. Enterprise Modelling for Common Understanding

Like other aspects of organisations, organisational rules can be examined and understood through enterprise modelling (EM), which provides an overview and helps to build a common understanding among stakeholders [18]. EM is conducted from various perspectives, such as rules and goals or actors and roles [19]. EM is valuable for designing IT systems and for understanding and designing socio-technical systems, including the organisational aspects independent of computational systems, such as rules.

To create enterprise models, a modelling language is required. According to Karagiannis & Kuhn [20], a modelling language consists of notation, syntax, and semantics and is further described using a meta-model [20].

1.4. The Context of This Study

This study is part of a design science research (DSR) [21] project that aims to develop a modelling language [20] with an accompanying method for understanding organisational rules in complex adaptive systems. It should be emphasised that the purpose is not automation, simulation, or legal reasoning about rules. Rather, the organisational rules in focus are mostly of the kind that requires human interpretation, and the foreseen language should be possible to use for tangible and participative enterprise modelling [22], in other words, working on a whiteboard with stakeholders.

DSR can be understood as five logically connected activities [23]: (1) explicate problem, (2) elicit requirements, (3) design artefact, (4) demonstrate artefact, and (5) evaluate artefact. Our main contribution so far in this DSR project focused on problem explication; In a recent systematic mapping study [4] we analysed existing modelling languages used to model organisational rules in the complex setting of collaborations. An analytical framework including 15 concepts from CAS theory, grouped into five themes, was developed and used to analyse what aspects of a CAS the 22 included modelling languages could represent.

In this paper, we integrate the CAS concepts from the framework of the previous study with the concepts found in the 22 languages, forming a conceptual model of organisational rule systems. In other words, the research aim is: to design a conceptual model that integrates previous conceptual modelling

Table 1
Analytical framework with CAS concepts grouped into themes

Theme	Concept
Components	Agent [13], Constraint [24]
Part-of	Structural Emergence [9], Multi-levelsystem [12], Environment [9]
Behaviour	Interaction [6], Event [10], Behaviour [10], Behavioural emergence [25]
Adaptation	Feedback loops [10], Adaptation [13]
Complexity	Messiness [7], Fuzziness, [8], Non-linearity [6], Non-determinism [6]

contributions of organisational collaborations with complex adaptive systems theory. Regarding the DSR cycle, the study contributes to the first iteration of requirements elicitation and artefact design.

The foreseen modelling language will be aligned with the most relevant parts in this conceptual model, which will, therefore, function as a meta-model of the modelling language. Exactly which these parts are must be informed by practitioner input from potential modelling language users. The next step will thus be to conduct a qualitative survey with participants of this group. The survey will serve two purposes. First, it will add practitioner input for a second iteration of the conceptual model. Second, it will provide input for the requirements elicitation of the foreseen modelling language.

A key difference between a meta-model and a modelling language is that the former does not necessarily have to be easy to use. For our purpose, we prioritise making the meta-model correct and comprehensive. A modelling language, on the other hand, in particular if used to create a common understanding among stakeholders, must be easy to learn and to use. Yet, more rigour is added to the design process, by grounding the foreseen, simple modelling language in a larger model that did not need to compromise its correctness.

The remainder of this paper is structured as follows. The methodology is presented in Section 2. The integration process between existing languages and CAS theory is presented in Section 3. The process and resulting model are further discussed in Section 4, and finally, Section 5 summarises the findings and presents future research plans.

2. Methodology

The above-mentioned analytical framework from the systematic mapping study [4], which will now be reused, is shown in Table 1.

For each theme and concept, the findings of the mapping study were reviewed for reusable constructs and patterns. However, the complexity theme, including the concepts messiness, fuzziness, non-linearity, and non-determinism, was treated as a cross-cutting theme.

These previous findings were examined and discussed through the lens of CAS theory to decide whether they should be included and how. Moreover, some additional constructs had to be added as bridges between the other constructs. As usual in design science [21], the process was not a straightforward waterfall but rather a back-and-forth between the different activities.

While modelling we have applied the following conventions:

- Powertypes with enumerations were used instead of attributes with enumerations. This manner of conceptual modelling requires the addition of "type" classes but has the advantage of paving the ground for future additions of for example relations among types.
- Association labels are omitted if they are considered self-evident or have little semantic meaning, such as "has".
- Multiplicities are only shown if not zero-to-many.
- Aggregation associations have a multiplicity of zero-to-many on both ends.

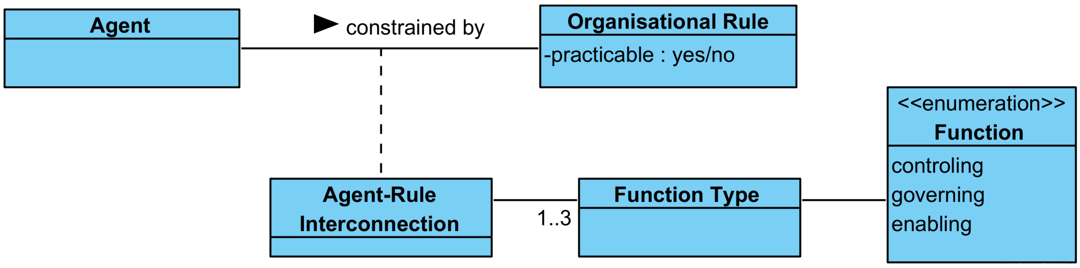

Figure 1: Model fragment of the concepts actor and organisational rule, and their interconnection.

3. The Conceptual Model Explained

As argued in Section 1.4, the conceptual model should be correct and comprehensive, but not necessarily easy to use. Already in this first iteration the size was considerable. The model includes:

- 44 classes, including enumerations
- 26 enumeration literals
- 56 associations

3.1. Components Theme

The components theme includes the concepts agent and constraint. These two elements are the building blocks of a CAS. All languages in the mapping study included both concepts, which was in fact an inclusion criterion. Some languages, such as the ARDI model [26], also represent that constraints control agents.

The findings of the mapping study show that rules and agents are interconnected, which indirectly also interconnect actors. According to CAS theory, a constraint, such as an organisational rule, makes certain types of interaction more likely and others less likely or even forbidden [24, Framework]. Moreover, the rules can have three different functions: A controlling rule tells an agent more or less exactly how to act. A governing rule states what is forbidden but leaves the remaining space to the agent's discretion. An enabling rule is a form of scaffolding that connects agents to others, for example, by establishing communication channels, increasing their possibilities to interact.

The interconnection between agent and rule is shown in Figure 1.

3.1.1. Agent

In the mapping study, as mentioned, all languages could represent agents of different types, either in the form of people, organisations, or roles. One fairly well-elaborated model was iStar [27], representing that an actor can be either an agent or a role. An agent plays a role in certain situations. For example, an organisational unit can take on the role as the product owner. This pattern resonates well with CAS theory since it emphasises the fuzzy borders between different organisational systems, in which the same actor can play a role in several different systems simultaneously. However, this notion could not be integrated with a more fundamental notion from CAS theory, namely that a complex agent can be viewed both as an agent and as an organisational rule system composed of rules and other agents. More details on how the model represents the multi-layered nature of CAS are given in Section 3.2.

3.1.2. Constraint

Several useful patterns were found for modelling organisational rules. First, Semantics of Business Vocabulary and Business Rules (SBVR) [28] and its sister standard Business Motivation Model (BMM) distinguish between two types of directives: directly practicable and not directly practicable. Second, in SBVR business rules can also have different levels of stipulated enforcement, from mere guidelines to

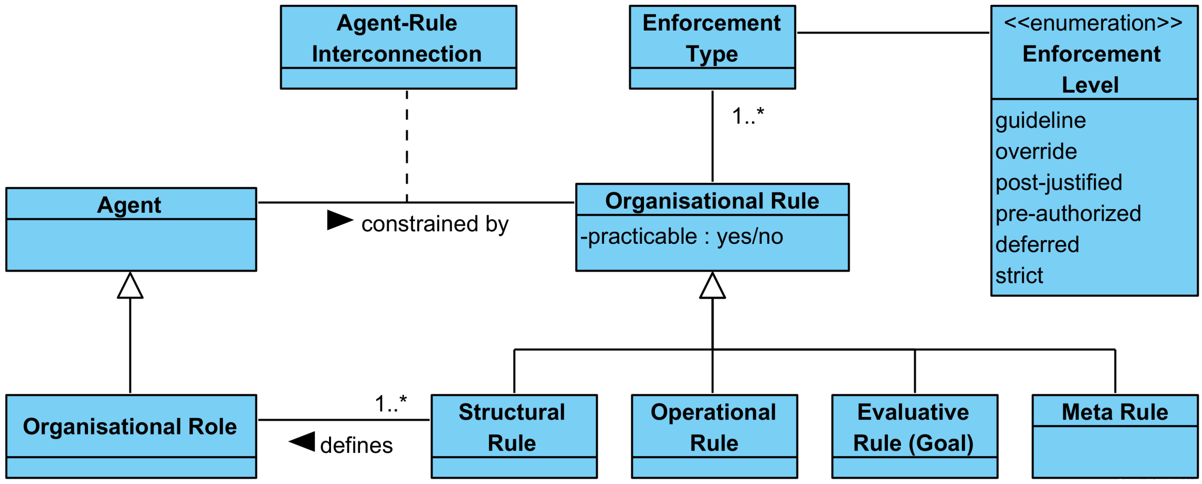

Figure 2: Model fragment of the expanded components actor and organisational rule.

strict enforcement. Third, the Collaborative Network Ontology (CPO) [29] represents that a collaborative network may have a shared goal.

From a CAS theory perspective, recognising that some rules need interpretation is important since it emphasises the non-determinism of agents. Identifying differences in enforcement level aligns with fuzziness, as it shows that it is not binary if a rule should be followed or not. Concerning goals, these are things that agents pursue. Contrary to most definitions, we consider a goal as a subclass of a rule. The reason is that, from a CAS theory standpoint, a constraint is something that makes an interaction more or less likely. This broad definition includes goals.

Furthermore, as pointed out by Burns & Flam [30], rules can have subclasses: structural, operational, evaluative, and metarules. A *structural rule* provides definitions of reality, including organisational roles, such as whom an enterprise considers its customer. For example, a definition in a business vocabulary is a structural rule. An organisational role cannot formally exist without being defined, or at least mentioned, in an organisational rule; An *operational rule* regulates what is allowed; An *evaluative rule* states what is desirable and is close to what BMM denominates a goal. A *meta-rule* is a rule about rules. An example of meta-rule, observed by most people, is that, in general, it is best to follow rules rather than break or try to change them [30].

Figure 2 shows the expansion of the core concepts actor and organisational rule.

3.2. PartOf Theme

The CAS PartOf theme includes the concepts multi-level system, environment, and structural emergence.

3.2.1. Multi-level System

Two representations of *multi-level systems* were found in the analysed languages: fractal (two papers) and non-fractal (four papers). Fractal means a model may be decomposed infinitely by applying the same decomposition mechanism. The EXTENDED Module [31] and IDEF0 [32] contained the first variant. In IDEF0, every function in a model can be broken down into its component parts and modelled as a separate system with unique functions. IDEF0 functions are also numbered in a way that shows the level of decomposition. As for the second method discovered, one example is AMENITIES [33], which represents how a cooperative system included both groups and organisations (that are not decomposable).

In a CAS, a complex agent, such as an organisation or organisational unit, is also a system itself composed of agents and constraints. In other words, an organisation should be viewed both as a system made up of lower-level agents, and as an agent that interacts with other agents according to rules.

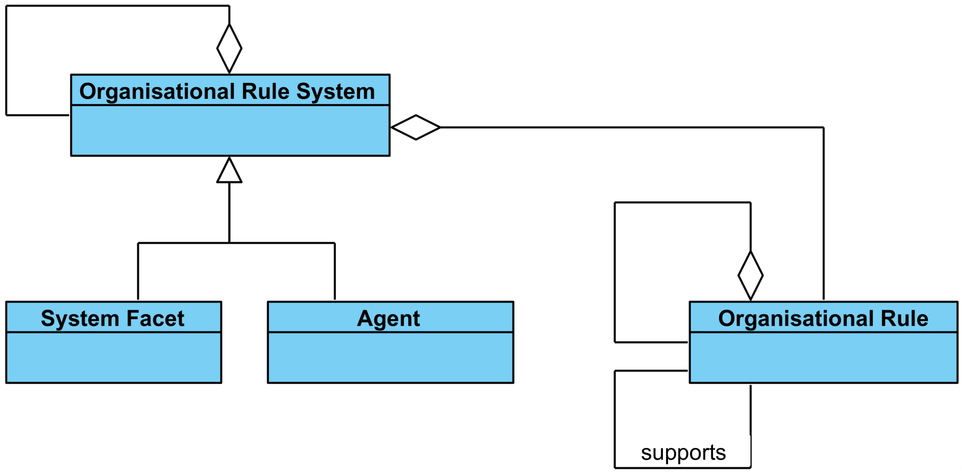

Figure 3: Model fragment of the concepts multi-layer system and environment.

A model representing an undetermined number of layers of a multi-layered system exhibits a fractal structure. Similarly to the property of decomposition levels in IDEF0, there can also be a property that indicates how many times a system model can be decomposed until the deepest leaf system is reached. This property can serve two purposes. First, it can provide information about the number of hidden layers that can unfold from a certain system. Second, a modelling language could define a pre-set number of model levels even if a fractal decomposition mechanism is used. In our model, we opted for using a fractal decomposition mechanism and not specifying the number of desired levels and.

The concept of a multi-level system is mainly shown in Figure 3. The decomposition level property is shown in Figure 4.

3.2.2. Environment

Several modelling languages were found to represent boundaries and the notion of *environment*. IDEF0 and iStar can also show how the modelled system affects its environment. SBVR and IDEF0 can also show that rules may come from outside of the system boundary. Moreover, SBVR can represent that, depending on the perspective, a particular rule can play the role of internal Directive for one actor but as an external Regulation for another. iStar could represent that different actors have an inner environment while also interacting with other agents, thus being each other's environment. In addition, iStar represents that a part of an actor can interact directly with a part of another actor without having to represent this interaction on a more general level.

The above findings of the mapping study suggest that there are, in general, two approaches to model the environment of an organisational system. One is to model the system boundary, showing that something is out there affecting the system, for example, by sending and receiving inputs and outputs. The second approach is to represent agent interaction, without specifying a construct for environment. The second approach was chosen for the model. Recall that, in our view, an agent is also a system, and CAS theory emphasises the fuzzy nature of reality, including fuzzy borders between systems. The question then became whether to represent this interconnection only via the rules that interconnect agents or through some other, more direct association that can represent other types of interconnections. There are probably good pragmatic arguments for the latter option, but since usability is not the focus of this model, the choice was the former option. In other words, no particular construct was added to represent the environment, and interconnections between agents were only represented indirectly via rules.

3.2.3. Structural Emergence

Structural emergence in CAS theory refers to the process where higher-order, organised structures or patterns emerge from lower-level components of a system. These emergent structures exhibit properties that cannot be fully explained or predicted by analysing the individual components alone. A simple kind of structural emergence is when patterns form by components. These patterns are made up of the components' relationships.

The findings with regard to the structural emergence concept included three aspects. First, some languages represent that something is part of something else. The EXTENDED Module represent that goals, and thus also other rules, can be formed by subgoals. Moreover, the SEMD meta-model shows that networks can emerge from multiple organisations. Additionally, the Generic Privacy Ontology represents that subunits, such as Groups, form Organisations.

Second, AMENITIES represented how rules can create new roles and other organisational realities.

Third, Collaborative Network Ontology (CPO), uses a construct denominated Topology to describe a Collaborative Network. The type of Topology can be Star, Peer-to-Peer, or Chain. The Topology is also characterised by its Power distribution, which can be Central, Equal, or Hierarchic, and its Duration, which can be Continuous or Discontinuous.

The first aspect is that something is part of or jointly leads to something else and relates to the discussion about levels and fractals above. An organisational rule system —being a CAS— is composed of actors and organisational rules. An organisational rule can often be broken down into more detailed segments, and, in the other direction, be aggregated into larger collections of rules. A resembling hierarchical pyramid is created by rules supporting other rules. The first aspect has already been included in Figure 3.

The second aspect, creating new organisational realities, relates to how new levels emerge in a CAS that grows bottom-up. The ability to create new organisational realities through structural rules, discussed in Section 3.1, is important in this process. The second aspect has already been covered in Figure 2.

The third aspect provides an example of structural emergent properties that can be used to describe a system. Two other characteristics from CAS theory that can be modelled in the same manner are what extent an organisational rule system can be considered messy or fuzzy.

The concept of structural emergence is shown in Figure 4. Note that only the third aspect is included in the figure since the first and second have already been represented in Figure 2 and Figure 3.

3.3. Behaviour Theme

The behaviour theme includes the concepts agent interaction, events, behaviour and emergent behaviour.

3.3.1. Agent Interaction

Several languages in the mapping study represent that agents act under the influence of rules. The ARDI model [26] represents how Regulatory Actors can design Policy Instruments, which in turn control the conduct of Institutional Managers. A similar representation was found in the Italian Business Network Contract ontology [34], which expresses that a Network Contract is associated with a Management Body. Moreover, the Generic Privacy Ontology [35] represents that an organisation has an organisational policy. In addition, the Italian Business Network Contract represents that a network contract has a management body. The model recognises that the rules in the contract must be interpreted and enforced, not only by the participants who should comply with it. Finally, SBVR [28] shows how actors, controlled by rules, participate in situations. For example, a certain situation, such that the total order amount exceeds 1000€, can trigger the inclusion of more rules or actors.

In short, the findings of the mapping study include how organisational agents are controlled by rules. They are also controlled by other roles that are responsible for enforcing rules. An interaction with rules occurs in a particular situation. All of this resonates well with the CAS theory. In a CAS, agents interact according to constraints. The interaction influences the events. By representing that the

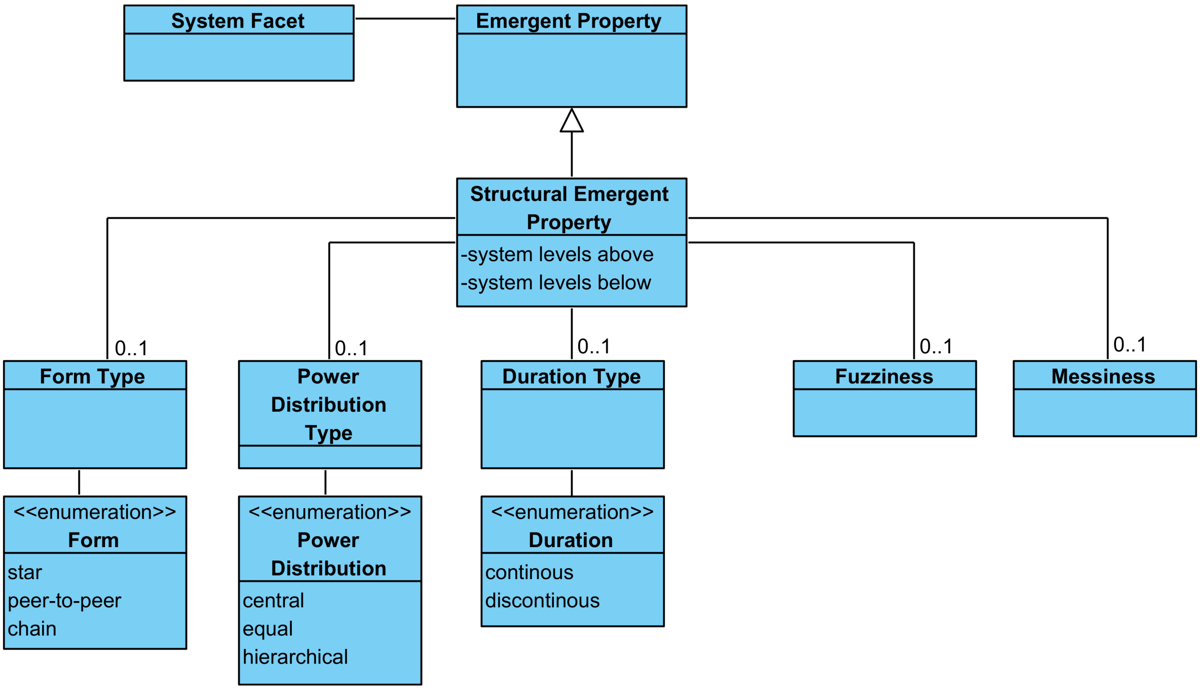

Figure 4: Model fragment of the concept structural emergence.

interaction happens in a certain situation, the model recognises the messy reality in which rules must be interpreted and enforced in an infinite number of possible situations.

3.3.2. Events and Behaviour

A simple modelling of *behaviour*, employed in seven of the studied articles, is to recognise that *events* can occur. This approach was used in, for example, the Process Life Cycle Information and Process Analysis Methodology [36] and the myKinMatters ontology [37]. In CAS theory, behaviour is formed by events.

The concepts of interaction, event, and behaviour are shown in Figure 5,

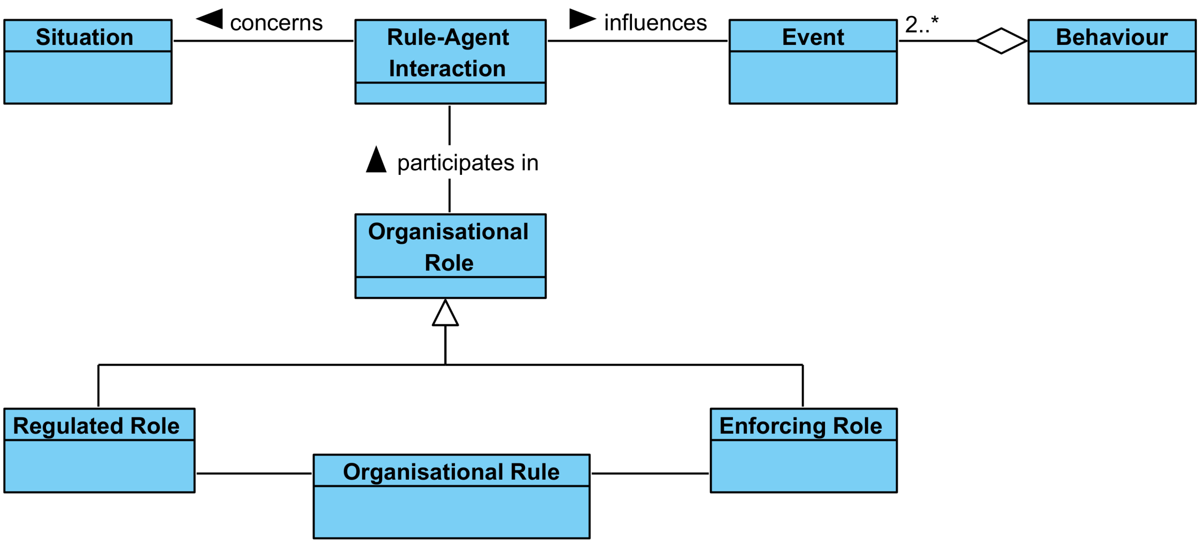

Figure 5: Model fragment of the concepts interaction, event, and behaviour.

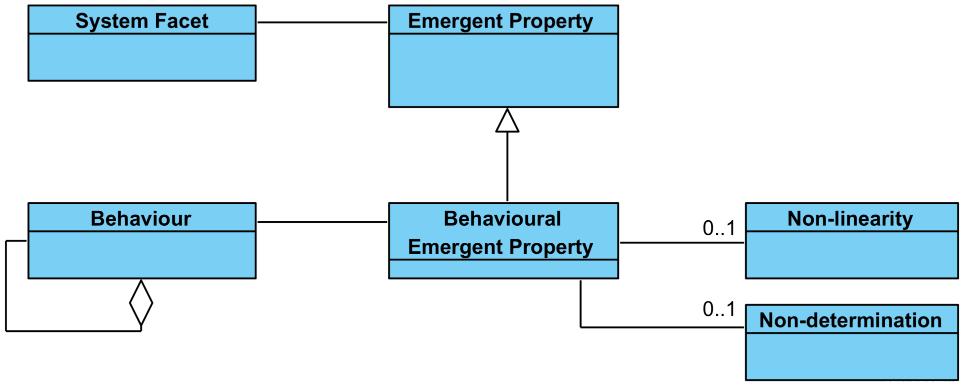

Figure 6: Model fragment of the concept behavioural emergence.

3.3.3. Behavioural Emergence

Emergent behaviour, understood as the collective behaviour of a system, is depicted using several (n = 5) modelling languages. The Collaborative Network Ontology (CPO) characterisesAlthough seven languages emergent behaviour through the concept of an Abstract Service, comprising Business Services. The Abstract Service also serves as the network's Common Goal. Another example is IDEF0, where outgoing flows from different Functions can converge and traverse the system boundary.

The findings of the mapping study suggest that a behaviour can be composed of other behaviours, which resonates well with the multi-layered nature of a CAS. Moreover, just as messiness and fuzziness can be considered structural emergent properties, as discussed in Section 3.2, the behaviour of a system can also be more or less non-linear and non-deterministic.

The concept of behavioural emergence is shown in Figure 6.

3.4. Adaptation Theme

The adaptation theme includes the concepts of feedback and adaptation.

3.4.1. Feedback

Although seven languages addressed feedback in some way, for example, through measurements, only two of them could indicate that the information is received by a particular agent. KiPPINOT-CORE [38] indicates that an agent is informed by an indicator's measurements. Furthermore, the Strategic Planning Ontology (SP Ontology) [39] indicates that an agent conducts an analysis of an objective.

According to CAS theory, a feedback channel is needed to ensure that the feedback loop closes effectively so that an agent receives timely information about the consequences of its actions, such as a rule change. The use of carefully defined indicators has a part in this. However, indicators can only be designed for behaviours that are in some sense expected and are usually expressed in quantitative terms. A comprehensive feedback channel must also be designed to catch unknown unknowns [40] associated with complex domains. That, however, will have to be addressed in future studies.

The concept of feedback is represented in Figure 7,

3.4.2. Adaptation

For adaptation to occur, constraints must be modified. Several modelling languages, for example the ARDI Model [26], represented how rules could be created. Although unilateral decision-making could be considered the default type of rule creation, other language also represented how rules are created through mutual agreement, or by an agent adopting existing rules made by others.

The adaptive nature of CAS implies that rules are not only created once but also modified and finally deleted. These aspects must be added to the conceptual model in the future.

The concept of adaptation is shown in Figure 8.

4. Discussion

The research aim of this study was to design a conceptual model of an organisational rule system. This was achieved by integrating empirical findings of CAS related modelling patterns from a previous systematic mapping study with a theoretical framework of concepts from CAS theory.

Some parts of the conceptual model raised more questions than others. Most importantly, to stay true to the multi-layered nature of CAS, we decided to model organisational rule systems as both a system facet and an agent facet. This solution is perhaps unfeasible to implement, but operationalisation is, on the other hand, not the purpose of this model, as explained in Section 1.4.

By integrating the findings from our previous systematic mapping study into a conceptual model, there is now a visual overview of the existing modelling patterns in this area, facilitating observation of the remaining research gaps. As also concluded in the mapping study, feedback channels and rule hierarchies, which relate to multi-level systems, need further exploration. Moreover, during this study, it became more apparent that how to represent the concepts in the complexity theme is far from evident and that the question of behavioural emergent properties needs to be better represented.

As stated, this study is a step towards a comprehensive conceptual model. However, so far, we have only included existing modelling patterns and CAS concepts, while avoiding introducing additional concepts. In that sense, the proposed model could after this first step towards a comprehensive model be denominated a minimum viable model. Complementing it with concepts from the literature about social rules, including law, could be a next step.

We have still not talked with the intended end-users to ask if a modelling method in fact would be helpful, and if so, which of all aspects would be of most relevance. Although the conceptual model already includes a total of 126 constructs, a modelling language that is still easy to use probably should not include more than around 15 constructs, preferably fewer.

5. Conclusion

In this study, we develop a conceptual model of organisational rule systems within the context of complex adaptive systems (CAS), integrating empirical findings from a previous systematic mapping study of modelling languages used to represent rules in organisational collaboration with theoretical concepts from the CAS theory.

The model reflects the multi-layered nature of CAS by viewing organisational rule systems as both systems and agents. It also represents a complete cycle of agent adaptation: from agents that are interconnected with and through rules, to agent interaction, which influences events, which form patterns of behaviours that agents learn about through feedback channels, allowing them to adapt by creating new rules.

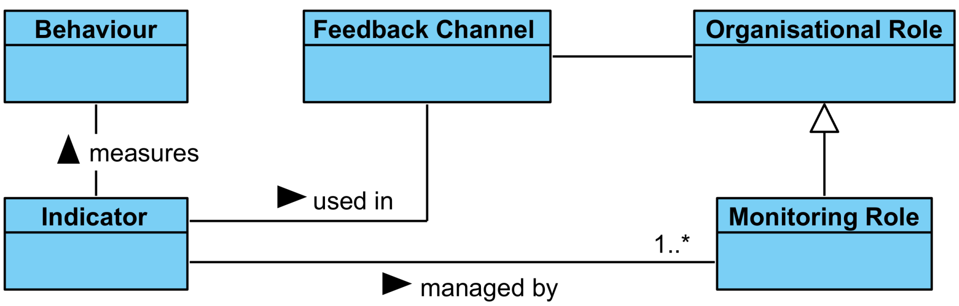

Figure 7: Model fragment of the concept of feedback channel.

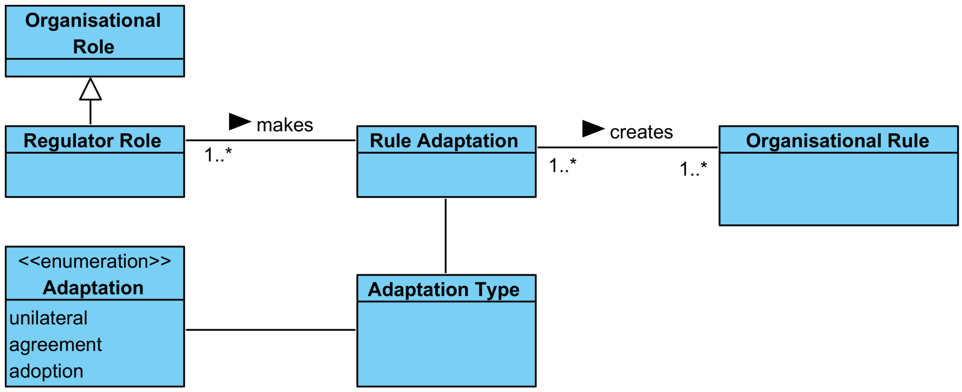

Figure 8: Model fragment of the adaptation concept.

The purpose of the model is not to be operationalised but to serve as a solid grounding for an easy-to-use modelling language. This process will rely on practitioner input to determine which of the many constructs included in the conceptual model are sufficiently important to include in a modelling language.

As expected, the conceptual model is still not very comprehensive. In particular, the areas of feedback channels, rule hierarchies, emergent behavioural properties, and how to model the concepts in the complexity theme, to some extent, remain. Future studies and design iterations are foreseen to further complement and improve the model. These studies can draw from literature about social rules and the study of heavily regulated organisations, including interviews with domain experts.

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