

# nADICO: A Nested Grammar of Institutions

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**Abstract.** We propose a refined institutional scheme derived from Crawford and Ostrom's *Grammar of Institutions* (GoI) that has been refined to provide a more comprehensive representation of conventions, norms, and rules, which extends to describing institutions in more detail but also allowing the expression of fuzzy aspects (e.g. the uncertainty about a sanction's occurrence). After initially reviewing the GoI grammar structure (also referred to as ADICO), we discuss its adoption as well as limitations. We introduce selected extensions and refinements that enable the grammar's ability to describe institutions in more detail, but also to capture more complex institutions as well as characteristics of institutions themselves, such as institutional regress.

Central features of our *Nested ADICO* (nADICO) include:

- A notion of nesting monitored and consequential ('Or else') statements, and
- a refined differentiation between norms and rules.

nADICO both enables a more comprehensive expression of institutions and extends the use of the original grammar into various application domains, while taking the initial step towards a more dynamic perspective on institutional modelling.

**Keywords:** Grammar of Institutions, Nested ADICO, nADICO, Institutions, Norms, Rules, Institutional Statements, Policy Modelling, Multi-Agent Systems

## 1 Introduction

Crawford and Ostrom's *Grammar of Institutions* [2] (GoI) is an approach to unify the expression of different kinds of manifestations of social behaviour (institutions), such as shared strategies (or conventions), social norms, and codified rules, while maintaining the ability to discriminate between these different types. To do so, it consists of five components, *Attributes*, *Deontic*, *Aim*, *Conditions* and an *Or else* - ADICO in short - that are necessary to specify *institutional statements*, such as rules. By restricting constitutive components to a minimum, this syntax offers a wide scope for the expression of institutional statements representing the different kinds of institutions, which we refer to as institution types for the remainder of the paper.

The generality of ADICO enables researchers to express various institutional views, including *institutions as stabilised equilibria* (e.g. [6], favoured by economics analysts), *institutions from a normative perspective* (e.g. [12], which concentrates on the behavioural perspective and is favoured by many researchers in the multi-agent systems

community (e.g. [9]), and *institutions as rules* (e.g. [7], a central subject of study in the New Institutional Economics movement).

In this work, we revise the grammar to extend its ability to capture institutions in more detail, while reviewing its interpretation of different institution types with the intent to offer interpretational prescriptions that are more faithful to the nature of the institutions the grammar represents.

In the next section (Section 2) we review Crawford and Ostrom's grammar and its adoption in different fields. Then in Section 3 we present Nested ADICO (nADICO).

## 2 The Institutional Grammar

### 2.1 Overview

The ADICO grammar consists of five components. Those include:

- *Attributes* – describe the attributes and characteristics of social entities (which can be individuals or groups) that are subject to the institutional statement (e.g. shared strategy, norm, rule). If not specified explicitly, all individuals (or members of a group/society) are implied.
- *Deontics* – a deontic primitive that describes either an *obligation* (e.g. represented as **must**), *permission* (**may**), or a *prohibition* (**must not**).
- *Aim* – the aim describes an action or outcome associated with the institutional statement. Only constraint put on an aim instance is that the action or outcome it describes must be physically possible, so their non-/compliance can be determined [2,13].
- *Conditions* – capture the circumstances under which the statement applies. This can include spatial, temporal and procedural elements. If not further constrained, the *conditions* component default to “at all times and in all places” [2].
- *Or else* – describes consequences that are associated with the violation of the institutional statement, i.e. the combination of all other components used in that statement. In Crawford and Ostrom's grammar, this component has constitutive role in classifying statements as rules.<sup>1</sup>

Using three statement types, one can construct institutional statements of increasing prescriptiveness. Parsing an institutional statement in the form of a *shared strategy* (*convention*) with this grammar yields an AIC statement:

**Drivers (A) hand their driver's license to the police officer (I) when stopped in traffic control (C).**

It effectively reflects a description of drivers' commonly observable behaviour when facing the request to hand over their licenses. From a normative perspective, this can be interpreted as a descriptive norm.

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<sup>1</sup> Crawford and Ostrom specify three requirements for an 'Or Else' statement: 1) It needs to result from a decision-making process by a collective that has the power to do so; 2) it requires the 'Or Else' component to be supported by another norm or rule statement that modifies the assigned deontic under the condition that the first rule is violated; 3) it requires the specification of a rule that specifies the responsibilities of a monitor.

In GoI parlance, a *norm* would extend a shared strategy with a prescription, expressed as ADIC:

**Drivers (A) *must* (D) hand their driver’s license to the police officer (I) when stopped in traffic control (C).**

This represents an unambiguous instruction to the driver who might feel threatened by an uncertain consequence of violation, or (if taking a strictly deontological perspective) perceives it as his duty to present his driver’s license, independent of any threatening consequences.

Finally, a *rule* (ADICO) would introduce consequences for non-compliance:

**Drivers (A) *must* (D) hand their driver’s license to the police officer (I) when stopped in traffic control (C), or else the police officer *must* enforce it based on traffic law (O).**

Here the driver faces explicit consequences, which, depending on the nature of his refusal, can result in material (e.g. fines) or physical sanctions (e.g. arrest).

## 2.2 Application fields, refinements and limitations

The ADICO grammar provides a semi-formal description of institutional rules that make them accessible for economic analysis (e.g. using game-theory, as done by Crawford and Ostrom [2]) and structured policy coding [?]. In the area of multi-agent simulation, Smajgl et al. [11] have used the grammar to model endogenous changes of ADICO rule statements in the context of water usage. Significant recent contributions that use the grammar in more depth include Ghorbani et al.’s MAIA framework [4], which represents a comprehensive attempt to translate Ostrom’s Institutional Analysis and Development Framework [8] into an agent-based model. Earlier, Ghorbani et al. [3] explored the notion of shared strategies as a fundamental statement type and differentiated their application across common, shared, and collective strategies.

Apart from a wide range of uses, the grammar has attracted some suggestions for refinement [10]. Our own interests in this area concern how to make the grammar more comprehensive, flexible and dynamic. There are two key issues in this context which we wish to emphasise.

First, the existing ADICO differentiation between shared strategies, norms, and rules (differing grammar components are used in those separate contexts) seems to compartmentalise this domain artificially to provide a neat match between grammar and institution types. In original ADICO terms, rules are assumed to have sanctions, whereas norms do not [2].

Second, in ADICO the notions of prohibition and obligation norms are mapped into a ‘discrete’ perspective. Other authors already have pointed out this limitation and claimed that a more continuous perspective [10] would be more applicable. It would seem that modelling the progression across differing institutional types requires more flexibility in specifying norms, beyond the discrete **may**’s, **must**’s, and **must not**’s. More flexible boundaries are desirable to support continuous adaptation so that a new and different norm may gradually emerge from or replace an existing one.

In this work, we take the initial step and address the first issue by introducing a nested approach to institutional statements, in the form of Nested ADICO.

### 3 Nested ADICO (nADICO)

In our work we shift the focus from the classification and isolated analysis of institutional types over to a more integrated view on institutions, smoothening their boundaries. Although this blurs the strict categorisation of the ADICO grammar, our refinements offer (a) the potential of capturing institutions in greater detail and their full complexity, (b) a refined interpretation between different institution types so as to prepare the modelling of institutional transitions.

#### 3.1 Nested institutional statements

**Vertical nesting (Institutional regress)** – We introduce the notion of nested institutional statements. These provide a more detailed, operational description of the consequences of actions (corresponding to the 'Or else' component of the ADICO grammar). We replace the original unstructured ADICO 'Or else' statement with a nested institutional statement. The first part of this statement (the 'ADIC') is what we call the *monitored statement* with respect to the second, nested part of the statement (the 'O' in the original GoI), which we call the *consequential statement*. Using vertical nesting one can express consequences using the same structural components as the monitored statement, thereby supporting a nested structure and hence a multi-level modelling of institutions, allowing the representation of institutional regress. That is, consequential statements may be interpreted as comprising their own *second-order monitored statements* backed by their own *second-order consequential statements*. This can support the interrelation and dependencies among connected institutions - certain additional institutions may be invoked and activated as a social consequence of failure to comply with some higher-level monitored statement. We call this nesting across different statement levels *vertical nesting*. Recall the example from Section 2:

Drivers ( $A_1$ ) must ( $D_1$ ) hand their driver's license to the police officer ( $I_1$ ) when stopped in traffic control ( $C_1$ ),  
**OR ELSE** ————— *2nd level* —————  
the police officer ( $A_2$ ) must ( $D_2$ ) enforce this ( $I_2$ ) under any circumstances ( $C_2$ ),  
**OR ELSE** ————— *3rd level* —————  
internal investigators ( $A_3$ ) must ( $D_3$ ) follow up on this issue ( $I_3$ ) in any case ( $C_3$ ).

Decomposing this into its syntactic elements, the structure for this rule instance can be interpreted as  $ADIC(ADIC(ADIC))$ . "Drivers" represent a *first-order violator*, while the police officer ( $A_2$ ) is *first-order sanctioner (reactor)*. In the case of violation at this level, however, the police officer becomes a *second-order violator*, and internal investigators ( $A_3$ ) become *second-order sanctioners (reactors)*, and potential *third-order violators*. This supports the more realistic expression of interrelated rules and, in principle, enables a generative approach to rule establishment.

**Horizontal nesting (Statement combinations)** – Violating a rule may often have multiple consequences - or, in the case of norms, the types of reactions and their occurrences may be unspecified or vague. Thus a strict 1:1 mapping will not be adequate for a generalisable institutional grammar. To accommodate this required generality, we propose

the expansion of statements on a given level, labelled as *horizontal nesting*, and introduce three logical operators for the combination of institutional statements: *and* (logical conjunction), *or* (inclusive disjunction), and *xor* (exclusive disjunction). Rephrasing the previous example in more detail in this format results in the following statement:<sup>2</sup>

Drivers (A<sub>1</sub>) must (D<sub>1</sub>) hand their driver's license to the police officer (I<sub>1</sub>) when stopped in traffic control (C<sub>1</sub>),  
**OR ELSE** ————— *2nd level* —————  
the police officer (A<sub>2a/b/c</sub>) must (D<sub>2a</sub>) enforce this (I<sub>2a</sub>) under any circumstances (C<sub>2a</sub>)  
**and**,  
depending on severity (C<sub>2b/c</sub>), must (D<sub>2b/c</sub>)  
    **either** fine the driver (I<sub>2b</sub>)  
    **or** arrest him (I<sub>2c</sub>),  
**OR ELSE** ————— *3rd level* —————  
internal investigators (A<sub>3</sub>) must (D<sub>3</sub>) follow up on this issue (I<sub>3</sub>) in any case (C<sub>3</sub>).

The structure of this statement is ADIC((ADIC *and* (ADIC *xor* ADIC))ADIC), and it depicts the clear specification of sanctions as a key characteristic for rules.

*or*-combinations are useful to express uncertainty associated with sanction diversity and occurrence in the context of social norms. Referring to the norm to keep well-mowed lawn in American neighbourhoods, we could express:

American home owners (A<sub>1</sub>) must (D<sub>1</sub>) mow their lawns (I<sub>1</sub>) under any circumstances (C<sub>1</sub>),  
**OR ELSE** ————— *2nd level* —————  
their neighbours (A<sub>2a</sub>) may (D<sub>2a</sub>) address that negligence (I<sub>2a</sub>),  
    **or** they (A<sub>2b</sub>) may (D<sub>2b</sub>) feel the need to explain themselves (I<sub>2b</sub>),  
    **or** their neighbourhood (A<sub>2c</sub>) may (D<sub>2c</sub>) reject them (I<sub>2c</sub>).

The respective nADICO expression is ADIC(ADIC *or* ADIC *or* ADIC).

**Nesting in monitored statements** – It should be noted that not only can the consequences be combined by operators, but also the monitored statements:

- (ADIC *and* ADIC) (ADIC) requires the co-occurrence of conditions to activate the consequence;
- (ADIC *or* ADIC) (ADIC) requires one or both statements to match;
- (ADIC *xor* ADIC) (ADIC) exclusively requires the match of a single monitored statement.

As with consequential statements, monitored statements can include combinations of multiple operators (e.g. (ADIC *and* (ADIC *xor* ADIC)) (ADIC)) to achieve horizontal nesting. Note that each of the individual monitored statements can optionally have its own vertical nesting structure (i.e. individual consequences), such as (ADIC(ADIC)

<sup>2</sup> We extend the index indicating the nesting levels along with letters that associate grammar components with the respective consequential statement(s) on that level. In this example, the second level comprises three statements (a, b and c), all of which share a common sanctioner A<sub>2</sub>, expressed as A<sub>2a/b/c</sub>, but only b and c share the same *Conditions* (C<sub>2b/c</sub>) and so on.

*and* ADIC(ADIC *or* ADIC)) (ADIC), however, when combined they additionally have a compound consequence.<sup>3</sup> Alternatively to the examples shown here, nADICO statements can be terminated by AIC statements (shared strategies/conventions), which are descriptive (e.g. to reflect behaviour change of individuals) in case of violations instead of prescribing behaviours.<sup>4</sup>

Figure 1 shows the complete nADICO grammar in the Extended Backus–Naur Form (EBNF) [5] capturing all nADICO statements, including the elementary ADICO institution types AIC (convention) and ADIC (sanction-less norm).

Fig. 1: nADICO grammar in EBNF

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attributes = "A" ;
deontic    = "D" ;
aim        = "I" ;
conditions = "C" ;
aic        = attributes , aim , conditions ;
adic       = attributes , deontic , aim , conditions ;
and        = "and" ;      (* conjunction *)
or         = "or" ;       (* inclusive disjunction *)
xor        = "xor" ;      (* exclusive disjunction *)
ws         = " " ;        (* whitespace *)
LB         = "(" ;
RB         = ")" ;
nadico     = adic | (* individual norm statement without sanction *)
            [ nadico [ , LB , ( nadico | aic ) , RB ] ] | (* vertical nesting *)
            [ LB ( nadico | aic ) , ws , and , ws , ( nadico | aic ) RB ] | (* combinations *)
            [ LB ( nadico | aic ) , ws , or , ws , ( nadico | aic ) RB ] |
            [ LB ( nadico | aic ) , ws , xor , ws , ( nadico | aic ) RB ] ;
statement  = aic | nadico ; (* nADICO statement (including conventions) *)

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### 3.2 Revised interpretation of institution types

The extensions to the original GoI affect the rigid classification principles the grammar offers. Given that we integrate the representation of social consequences of norm violation into the grammar, we lose the ability to differentiate between norms and rules based on the mere existence of an 'Or else' component. Instead we use characteristics that are not directly reflected in the original grammar. This includes the nature of the monitor. In Crawford and Ostrom's conceptualisation, monitors are essential to constitute rules, along with the previous process of collective action (see Section 2).

The requirement for a monitor is a useful criterion; however, we must equally assume that monitors exist for norms, as supported by a wide range of literature [1]. The GoI [2] only prescribes monitors for rules, in accordance with the GoI's assumption of sanctions only for rules, and its focus on explicitly formalised aspects of an institution. For a more inclusive perspective, however, it seems necessary to consider the nature of monitors also for normative statements. The inclusion of the monitor for norms has equally been discussed by Schlüter and Theesfeld [10], who suggest a set of monitor types but are not explicit about their association with norms and rules.

<sup>3</sup> As an example imagine the case suggesting that drivers should not speed, but also should not drive drunk, for both of which we assume individual consequences. However, if combined, both actions can have consequences beyond the individual sanctions, such as driver's license suspension based on demerit points.

<sup>4</sup> Note that conventions in ADICO are equivalent to descriptive norms, while the norms in ADICO are of injunctive nature.

Table 1: Monitor types

Monitor type	Institution type
Internal monitor	Personal Norm
Social monitoring Informally assigned monitor(s)	Social Norm
Formally assigned by private entities Formally assigned by legislative body	Rule

We interpret the existence of a structured and clearly specified collective action<sup>5</sup> process, such as majority-based group decision-making, with an outcome that is known to potential violators as a

differentiation criterion between norms and rules. This allows the classification of the suggested monitor types as shown in Table 1.

A limitation of the work of Crawford and Ostrom [2] and Schlüter and Theesfeld [10] is the lack of *clear differentiation between institution monitor and enforcer/sanctioner*. The grammar presupposes that the monitor is also the enforcer, which can be sufficient in some cases. However, for rules we would generally assume a potential differentiation between an entity that monitors an institution and an entity enforcing it, such as a government as regulative body that assigns enforcement duties to specialised enforcement entities such as the police (and in principle an even more refined differentiation by assigning the task of sanctioning to a judicial body). The effectiveness for social norms, in contrast, oftentimes relies on both the fact that a) the monitor is *not* clearly specified, and b) that monitor and enforcer are generally a unified entity<sup>6</sup> that considers itself directly affected by norm violations and thus feels inclined to act as an enforcer. A core motivation for the specification of rules, in contrast, is the clearly specified duties of both monitor and enforcer (which can either be captured as role descriptions or be expressed in great detail using nADICO statements themselves). A further aspect for the differentiation of norms in contrast to rules is the *uncertainty about the consequences involved*, the fuzziness of which we see as a strong motivator to comply with norms. We thus think that those characteristics – the clear vs. fuzzy interpretation of 1) monitor/enforcer and 2) consequences – are more significant for a distinction between norm and rule in a general grammar of institutions than the mere existence of a sanction.

This has consequences for the interpretation of nADICO statements. For rules we expect a *clear specification of the sanctioner* and/or its attributes (which are often implicitly captured by specifying roles), and, if differentiated from sanctioner, the specification of the monitor. Secondly, an indicator for the existence of rules when analysing nADICO expressions is the *clear specification of consequences*, and, if statement combinations (*horizontal nesting*) are used, the use of *and* as well as *xor* operators (e.g. to express graduated sanctions). For norms, in contrast, we would initially expect a *fuzzy specification of sanctioners*. This becomes a generic placeholder for the *attributes* component of a consequential statement (such as ‘\*’) implying *social monitoring*, or (an) *informally assigned sanctioner(s)*, such as a person that is affected by norm violation and simply acts as self-assigned sanctioner. Over time the nature of the sanctioner can transition between those types (see Table 1). However, unlike in the rule case (and specified by Crawford and Ostrom [2]), no collective action is involved. If horizontal nesting is used for norms, the *uncertainty about the sanctions involved* is expressed by

<sup>5</sup> Recall that collective action is another ADICO criterion to constitute rules (see Section 2; [2]).

<sup>6</sup> Note that the differentiation into monitor and enforcer for rules may not always hold (e.g. police officer as monitor and enforcer); in any case we would still expect a clear specification/characterisation in case of such a unified representation.

the use of *or* statements that combine possible (e.g. experienced) sanctions and express the fuzziness of sanctions that are applied in a non-exclusive manner (e.g. an individual's misstep can be sanctioned multiple times by different sanctioners applying the same or different sanctions, or not be sanctioned at all). Using this revised interpretation, nADICO enables a more comprehensive representation of and more nuanced differentiation *between* norms and rules.

## 4 Conclusion and Future work

In this paper we have introduced nADICO, an extension of the Grammar of Institutions. We have extended the original grammar's expressive power and generalisability of its application by introducing the notion of nested monitored and consequential ('Or else') statements and a refined differentiation between norms and rules. To operationalise the grammar, in future work we will introduce a fluid notion of deontics that allow the modelling of transitions between different institution types.

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