Formalising Situatedness and Adaptation in Electronic Institutions

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Abstract. Similarly to institutions in human societies, Electronic Institutions (EI) provide structured frameworks for Multi-Agent Systems (MAS) to regulate agents' interactions. However, current EIs cannot regulate a previously existing dynamic social system and deal with its agent population behaviour changes. This paper suggests a solution consisting of two EI extensions to incorporate situatedness and adaptation to the institution. These two properties are usually present at an agent level, but this paper studies how to bring them to an organisational level. While exposing our approach, we use a traffic scenario example to illustrate its concepts.

1 Introduction

Historically, societies have been organised based on conventions that individuals conform and expect others to conform [1]. Within organisations, conventions are explicit and are stated in terms of rules, protocols or both. In the context of Multi-Agent Systems (MAS), Electronic Institutions [2] are meant to follow the same principles.

An Electronic Institution (EI) is an MAS framework designed to guarantee previously defined social conventions. These conventions are designed to let the whole system achieve certain implicit goals. For instance, traffic rules try to improve traffic flow and to avoid accidents. These social conventions support agent coordination which typically has been handled from two main approaches [3][4][5]: considering the individual perspective of agents —so conventions can emerge— or a global organisational perspective —using infrastructure to support them—. An EI provides an organisational approach that regulates the agent interaction, thus the institution follows a global coordination perspective instead of an individual approach. More concretely, an EI is a *self-contained* and *static* organisational framework. By *self-contained* we mean user interaction solely occurs inside the institution. This is the case, because an EI mediates all messages among its participants. Also, and EI's social conventions do not change during its execution, so we consider it is *static*.

The problem arises when we have a dynamic social system —we call it *world*— and we want to enhance it by adding an EI. In this manner, we pursue enhancement by addition of EI's regulating capabilities. In this context, the fact of being *self-contained* and *static* becomes a limitation. Instead of being *self-contained*, we need the institution to be aware of the *world* it is added to. Even more, the institution should adapt to changes of this dynamic social system.

Our proposed solution to cope with this limitation is to extend an EI into a *situated autonomic* organisational framework. By *situated* we mean it is aware and can induce changes in the external social system (it is bound to *world*). And by *autonomic* we mean it can autonomously adapt to changes in the dynamic existing social system. We envisage the EI as a whole, *autonomic* and *situated* in a *world*. This vision at organisational level is very similar to autonomous situated agents at individual level. Thus, we conceive our proposed extension to EI as bringing to an organisational level two agent properties: situatedness and adaptation.

Specifically, we consider the institution situatedness as an awareness of its *world* (society, organisation or MAS) and its capacity to induce changes on it. In this paper, we formalise and extend some concepts used in a previous approach [6] to situate an EI. Besides, we envision adaptation as a goal-driven mechanism to change conventions. Societal changes, such as changes in agent behaviours or properties, may affect negatively in the fulfilment of organisational goals. Just as agents must adapt in order to succeed, Electronic Institutions should be able to adapt to fulfil their own global goals —which may differ form individual ones— . Thus, an extended institution is able to modify its conventions to improve the system's effectiveness to accomplish the organisational goals —it may also improve the system's efficiency—. This adaptation can also be seen as a reconfiguration aspect of autonomic computing, where systems are able to reconfigure themselves without human intervention [7]. In this paper, we formalise and extend some concepts used in previous approaches to situate and EI [6] and to adapt it [8].

Along this paper we use a traffic scenario as an example to illustrate introduced concepts (see Figure 2). In this scenario, an Electronic Institution acts as a *Traffic Regulation Authority*. Most agents play the role of cars, but we also consider policemen agents which act on behalf of the institution. These agents interact in a two-road junction, each road having two lanes in opposite directions. Lanes entering the junction have traffic lights controlled by our institution. When driving, cars enter and leave this crossroads at/from random sides. Moreover, cars may decide not to stop at red traffic lights, if this is the case and a policeman sees this traffic violation, it will sanction the car by subtracting points from its driving license. Finally, cars can collide. Collisions have an associated emergency protocol, in which a tow truck takes them from the crossroads to a garage to be repaired.

The rest of the paper is structured in five sections. Section 2 introduces Electronic Institutions to settle the basis for subsequent sections, which are devoted to situatedness and adaptation. Section 3 presents the so-called *Situated Electronic Institution*, and section 4 defines the notion of *Autonomic Electronic Institution*. Next, both approaches are compared with their related work in section 5. Finally, section 6 exposes the conclusions and outlines paths to future research.

2 Electronic Institutions (EI)

An *Electronic Institution* (EI) is an interaction framework for Multi-Agent Systems (MAS). One of the main objectives is to guarantee that its conventions —interaction protocols and rules— are followed by participant agents, which interact via dialogical actions. This is achieved by communication mediation, so that EIs filter out non-permitted actions. Figure 1 depicts this scheme. Participant agents are considered to be external to the institutional framework, and they interact through an institution wrapper called *governor*. Nevertheless, the institution delegates its functions to a special kind of agents, the so called *staff agents*. Accordingly, the definition of an EI is shown below and some of its components are discussed in next subsections:

Definition 1 *An Electronic Institution is a tuple* $EI = \langle DF, DC \rangle$ *[9]:*

- $DF = \langle O, M_I, ST, L_{CL}, L_E \rangle$ *stands for Dialogical Framework and provides a context for agent interactions, which are speech acts. Its components are: an Ontology* O*, a set of Information Models* M_I *—to keep information about EI's participants and activities at run time—, a Social structure* ST *—roles and their relationships—, a Communication Language* L_{CL} *—detailed in section 2.1—, and an Expression Language* L_E *—to specify conditions with a constraint language* L_C *and their consequences in an action language* L_A*—*
- $DC = \langle PS, NS \rangle$ *stands for a Deontological Component which is a set of conventions that constrains possible illocutionary exchanges and manages the responsibilities established within the institution. Its components are:* PS *as a Performative Structure and* NS *as a Normative Structure, both are described in subsequent sections.*

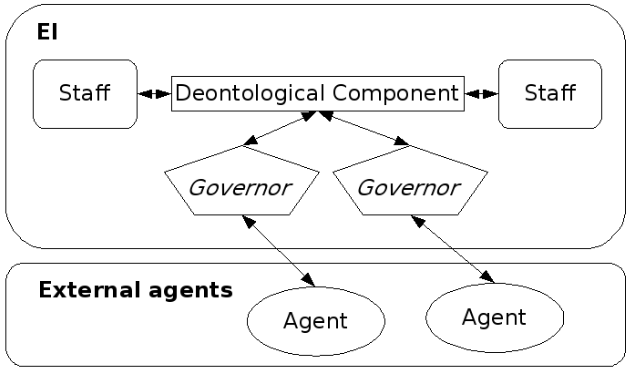

Fig. 1. Within an EI, participant agents interact through illocution messages mediated by their *Governors*. A Deontological Component and *Staff* agents guarantee the compliance of conventions.

2.1 Communication Language

The *Communication Language* (L_{CL}) is the language used by agents to utter their messages. Its expressions, called *illocutions* (I), are defined in terms of:

$$I ::= \iota(orgA_i : orgR_i, dstA_j : dstR_j, msg, t)$$

where there is an illocutionary particle ι (e.g. `request`, `accept`, `inform`...), its sender (an agent identifier $orgA_i$ and the role $orgR_i$ it plays), its receivers (an agent identifier $dstA_j$ or its role $dstR_j$), a message content $msg = f(params)$ and a time stamp t[1]. As an illustration, the following message could appear in the traffic scenario when police officer 'Bond' informs car 'Shiny' that it has a 10-point fine at time 1: $\texttt{inform}(\texttt{Bond} : \texttt{policeman}, \texttt{Shiny} : \texttt{car}, \texttt{fine}(10), 1)$

2.2 Performative Structure

A *Performative Structure* (PS) defines those conventions that regulate the flow of illocutions in an institution. The whole activity of an EI is a composition of multiple, concurrent dialogic activities —the so called scenes— involving different groups of agents playing different roles.

Each scene is specified by means of a finite-state directed graph, with nodes representing states and arcs defining those relevant actions that imply state transitions. It also includes some restrictions about time variables or how many agents can play a given role.

[1] EIs have a distributed architecture assuming a synchronised time

2.3 Normative Structure

The *Normative Structure* (NS) [10] defines a normative level in our Deontological Component. As described in [10] PS and NS are distributed and controlled by staff agents, called *Scene Managers* and *Normative Managers*. Briefly, a NS consists of a *Normative State* (S) and a set of *Rules* (R) that can update this state[2]:

$$
\begin{aligned}
NS \quad &= \langle\, S, R \,\rangle \\
S &= \{\, p_1 \ldots p_{n_S} \,\},\ p_i := \mathtt{utt}(I) \mid NP,\ NP ::= \mathtt{per}(I) \mid \mathtt{prh}(I) \mid \mathtt{obl}(I) \\
R &= \{\, r_1 \ldots r_{n_R} \,\},\ r_i \textit{ is a Rule} ::= Cond \Rightarrow Conseq \\
&\quad r_i : \mathbb{S} \times \mathbb{C}ond \rightarrow \mathbb{S} \\
&\quad Cond ::= \mathtt{utt}(I) \mid NP \mid Cond, Cond \\
&\quad Conseq ::= \mathtt{add}(NP) \mid \mathtt{remove}(NP)
\end{aligned}
$$

Normative State (S) contains a set of statements called *Normative Positions* (NP), which represent obligations (`obl`), prohibitions (`prh`) and permissions (`per`) associated to illocutions (I). This state can be updated by agents utterances (`utt`) and *rules* (R) [11]. A *Rule* consists of a condition and its consequences. When it is triggered by any combination of uttered illocutions (`utt`) and NP, it adds or removes NPs to S. See section 3.2 for a normative example in the traffic scenario.

3 Situated Electronic Institutions

In Multi-Agent Systems (MAS), agents interact within a environment. In some cases, this environment is solely composed by the set of agents, so for an agent the rest of agents constitutes its environment. Likewise, an Electronic Institution (EI) is an open MAS[3] that provides an interaction mediated environment within the institution itself, so we can refer to it as *EI inner environment*. In fact, as section 2 describes, an EI meditates agent interaction through *governors* to guarantee that defined protocols and norms are followed. This means that EIs have total control over this *EI inner environment*.

[2] We use uppercase letters to denote sets of elements (e.g. R is a set of rules) and lowercase letters to denote their elements (e.g. r_i is a single rule). In addition, when defining functions, we use blackboard letters to denote their domains (e.g. $\mathbb{S}$ is the domain of all possible *normative states* S).

[3] By open MAS we mean systems populated by heterogeneous and self-interested agents, that are not known beforehand, may vary over time and can be both human and software agents developed by different parties. Hence, we can not expect participants to follow the social conventions established by an EI.

In this paper, we propose to extend an EI to be able to interact with a previously existing environment, so that we relax total control in favour of interoperability. We call this extended institution a *Situated Electronic Institution* (SEI). The existing environment —we call it *world*— can be any social system —society, organisation or MAS— having individual actions and interactions that are relevant to our institution. These actions and interactions in the *world* can be illocutions and non-verbal actions. The SEI-*world* relationship is accomplished by attaching a SEI on top of a *world* (see Figure 2). In this way, a SEI can perceive *world* facts and induce changes on it.

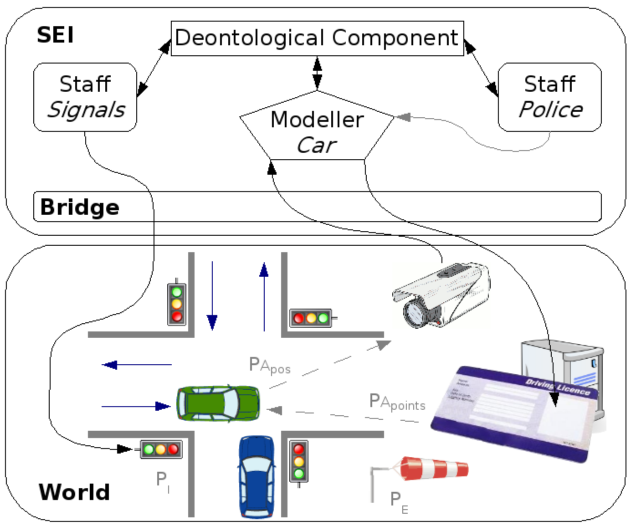

Fig. 2. A *Situated Electronic Institution* (SEI) in our traffic example. There is a communication *Bridge* between our SEI and the *World* it is situated in. This *bridge* allows *staff* agents to access certain *world* elements as *properties* (about modelled agents P_A, institutional issues P_I, or environment facts P_E). *Modellers* are specialised *governors* that model a *world* entity as if it was a regular external agent in an EI.

We say that a SEI is *situated* in this existing environment because it receives information about the environment, processes it, and induces some changes in the *world* to try to enhance its performance given some goals[4]. We consider a SEI has a model of the *world*, which maintains —according to external inputs— and updates —translating changes to external environment—. Similarly to agent level, at organisational level *world* may be also partially observable by a SEI. We also assume SEI's control over this *world* is quite limited, since it can only induce a limited amount of changes in it. Hence, a SEI can be defined as an extension of previous EI.

Definition 2 *A Situated Electronic Institution is a tuple* $SEI = \langle DF', DC, B \rangle$*:*

– DF' *stands for a previous Dialogical Framework extended with what we call* world*'s entity* Modellers *and* Properties.

[4] These goals are implicit in protocol and rule definitions.

– *DC corresponds to the Deontological Component of an EI.*
– *B stands for a Bridge, a communication channel with the world.*

3.1 Modellers and staff agents

Since a basic EI is a persistent SW system, it uses its *Information Model* (M_I) to keep information about EI's computational state in the form of attributes. Now, in a SEI, we call *Agent Properties* ($P_A \subseteq M_I$) to those attributes that keep the institutional state of each external agent (e.g. agent's credit or position), *Environment Properties* ($P_E \subseteq M_I$) to those attributes about global facts independent of the institution activity (e.g. date or weather) and *Institutional Properties* (P_I) to attributes related with global facts directly or indirectly influenced by the institution (e.g. the number of collisions which may be influenced by traffic lights' colours).

Some *external agents* of a SEI are represented by relevant *world* entities that are not controlled by the institution. Thus, a SEI has specialised *governors*, we name *Modellers*, in charge of modelling and interacting with these *world* entities. Thus, a *world* entity can be treated by the SEI as if it was a regular participant agent.

The information between SEI and *world* flows in two directions. On the one hand, a *Modeller* models a *world* entity by accessing the *world* and extracting relevant information about a certain entity. As a result, a *Modeller* keeps track of its corresponding entity *Agent properties* (P_A) and utters illocutions when its entity performs actions that are relevant to the institution. On the other hand, a *Modeller* translates interactions from SEI into changes in its *world* entity's *Agent properties* (P_A). Figure 2 illustrates this process in our traffic scenario. First, the "Car modeller" gets its car location ($P_{A_{pos}}$) by processing the camera information. If this car (c) is entering the road junction through a given lane ($lane_{id}$), the *modeller* generates the illocution '$\mathtt{inform(c:car, :policeman, entryJunction(lane_{id}), t)}$'. This illocution informs all policemen in the 'Crossroads' scene that the modelled car has performed the *entryJunction* relevant action. Later, if *modeller* is asked to decrease car's driving license points ($P_{A_{points}}$, see section 3.2), it will contact the *Traffic Regulation Authority* to perform this operation.

We see the institution situatedness as an awareness of the *world* where it is situated. Thus, we consider a SEI is aware of its *world* in the sense that it models and affects it. However, its *world* may or may not be aware of this SEI, depending on the domain. Domains present some restrictions on which information can be accessed and/or updated, which determines the level of SEI-*world* interaction and awareness. For example, in our traffic scenario, if the car's position is retrieved with camera's image processing, this car may probably not be aware of the SEI. In contrast, if the car is equipped with a GPS[5] and sends its position to the *Traffic Regulation Authority*, it may probably be aware of the existence of a surveillance system like the SEI.

On the other hand, there may be some *world* entities directly controlled by the institution. In this case, instead of a *Modeller*, a SEI has *staff agents* in charge of them. Figure 2 depicts an example in the traffic scenario. where an *staff agent* called "Signals" sends information to the *world* to set a traffic light colour (P_I). *Staff agents* can also interact with *Modellers* to access to *Agent Properties* (P_A) or read *Environment Properties* (P_E, e.g. the wind's direction).

3.2 Norms

We call *relevant actions* to those actions —or interactions— in a SEI's external environment (*world*) that affects its institutional model. Consequently, a SEI perceives or induces these *relevant actions* and bind them to the *world*. Within *relevant actions*, we distinguish between: *allowed actions* —those that follow social conventions— and *non-allowed actions* —the rest of *relevant* actions—.

Moreover, we use a *norm* to refer to a social conventions regarding an agents' interaction. Thus, *allowed actions* are those that follow *Norms*. Accordingly, we consider that a *norm* can be violated if agents do not follow its convention that is if agents perform *non-allowed actions*. On the other hand, we use *rule* to identify an expression that defines the consequences of agents' actions. Hence, we can use a *rule* to define the consequences of a *norm* violation.

In an EI, most social conventions are specified through protocols so that *governors* filter out those illocutions not following them (*non-allowed actions*). In this way, an EI grants no participant can violate these conventions. In contrast, a SEI does not have such control over the *world* since it cannot prevent *world* entities from performing actions (or interactions). Thus, when designing a SEI, we have to pay special attention to the fact it cannot prevent participants from violating *Norms*. Consequently, a SEI needs to specify the consequences of violating these conventions with rules added to its *Normative Structure* (NS, see section 2.3).

As an illustration, Figure 3 contains an example in our traffic scenario. First, it exposes a social convention (n) about respecting traffic lights. Next, taking into account that a SEI cannot hinder agents in performing non-allowed actions, the institution's *Normative Specification* (NS) includes a *rule* r to define the consequences of violating this *norm*. This *rule* should say that "any car violating the norm will be fined". However, our example delegates violation judgements to *staff agents* ("Policemen", in this case). Therefore, the corresponding rule codifies

[5] A Global Positioning System sensor device.

the obligation of a "Policeman" to fine a car when it informs the car went through a red light. Finally, the example shows an execution case. It starts with the empty normative state S_0. Then, when a "Policeman" informs that a car has gone through a red traffic, the original normative state incorporates the corresponding illocution, resulting in S_1. Afterwards, a *Normative Manager* applies *rule r* by removing previous illocution and adding an obligation to normative state S_2.

S.CONVENTIONS:	n	= "cars cannot go through a red light"
SPECIFICATION:	NS	$= \langle S_0 = \{\}, R = \{r\}\rangle$
	r	$= utt\ (\ inform(x, policeman, y, car, noStop(Tlight), t_i)\ )$ $\Rightarrow add\ (\ obl\ (\ inform(x, policeman, y, car, fine(5), t_{i+1})\ )\ )$
EXECUTION:	S_1	$= \{utt\ (\ inform(p, policeman, c, car, noStop(Tlight), t_1)\ )\}$
	S_2	$= \{utt\ (\ inform(p, policeman, c, car, noStop(Tlight), t_1)\ )\ ,$ $obl\ (\ inform(p, policeman, c, car, fine(5), t_2)\ )\ \}$

Fig. 3. A *Normative Structure* example in a SEI situated in our traffic scenario.

3.3 Bridge

The *Bridge* (B) is an asynchronous bi-directional communication channel between our institution and the *world* (in [6] it was conceived as a channel connected to a multi-agent simulator). This channel is used by *Staff agents* and *Modellers* to obtain information from the external environment and to induce changes in *world* as explained previously. It provides access to manage *Agent*, *Institutional* and *Environment properties*.

Basically, this *Bridge* comes from an implementation requirement since it binds our SEI and its *world*. From an implementation perspective, although it is a single concept, it may be distributed among different APIs (Application Program Interfaces) to access different programming objects that interact with *world* elements.

4 Autonomic Electronic Institutions

The aim of an *Electronic Institution* (EI) is to guarantee that its defined protocols and rules are followed by its participant agents. These protocols and rules have been designed to pursue some implicit goals. However, as the profile of agents may differ among different populations, original protocols and rules may not lead to design goals. We can avoid this by extending EIs with an adaptation mechanism that allows institutions to adapt to these societal changes. Hence, we define an *Autonomic Electronic Institution* (AEI) as an electronic institution that can autonomously adapt to achieve a set of defined goals. We propose goal fulfilment to become the driving force for adaptation within the context of a rational world assumption. In this manner, an AEI has a *feedback* mechanism —centralised or distributed— with three main components: (1) an *objective* to define expected values of certain properties, (2) the corresponding observed *properties* and (3) a *mechanism* to specify how to reconfigure the institution to accomplish its objective depending on these observations (see Figure 4). Thus, we can define an AEI as an extension to an EI with these new elements.

Definition 3 *An Autonomic Electronic Institution is a tuple* $AEI = \langle DF, DC, G, TF \rangle$

- DF *and* DC *stand for a Dialogical Framework and Deontological Component*
- G *stands for institutional Goals*
- TF *stands for Transition Functions*

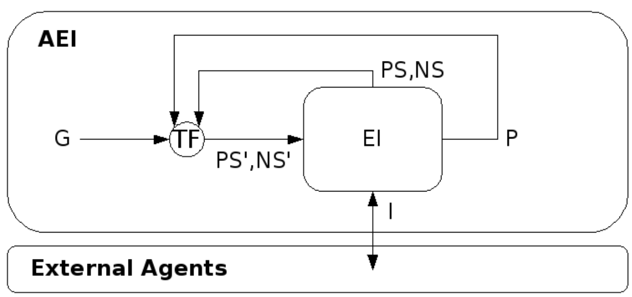

Fig. 4. An *Autonomic Electronic Institution* (AEI): *feedback* mechanism compares *observations* (prop. P) with their *expected values* (Goal G) and self-reconfigures (Perf.Struct. PS & Norm. Struct. NS) using Transition Func. (TF). External agents exchanges illocutions (I) through the institution.

4.1 Institutional Goals

Institutional Goals (G) specify desired values for observed properties P. These properties belong to the information model ($P \subseteq M_I$), and correspond to information about agents, the environment or the institution itself (see section 3.1). Goals have the following components:

$$\begin{aligned}
G = \ & \langle GS, \Gamma \rangle \\
& GS = \{\, gs_{P_1} \ldots gs_{P_{|GS|}} \,\},\ gs_{P_i} = \langle range_{P_i}, \gamma_{P_i} \rangle \\
& \quad \gamma_{P_i} : \mathbb{P} \to \mathbb{R} \in [0..1] \\
& \Gamma \quad : \mathbb{GS} \times \mathbb{P} \to \mathbb{R} \in [0..1]
\end{aligned}$$

- *Goal Specifications* (GS): is a set of goal specifications over each observed property (P). Each goal specification (gs_{P_i}) is a definition of a property value expected range ($range_{P_i}$) and a function that evaluates its fulfilment grade (γ_{P_i}). This grade is a normalised real value between 0 and 1, being 1 the completely satisfied grade. In our *Traffic Scenario GS* tries to keep the number of norm violations below ten ($0 \leq P_{I_v} \leq 10$) and a minimum number of policemen ($0 \leq P_{I_p} \leq 1$).
- *Objective Function* (Γ): function that computes overall goal satisfaction (a real value between 0 and 1, 1 meaning completely satisfied goals) from defined goals and current observations. Following our example, we would get maximum goal satisfaction having no violations while no policemen are deployed in our traffic scene with a weighted aggregation function [12].

4.2 Transition Functions

Transition Functions (TF) specify how the institution can change its organisational structure with the aim of increasing its overall goal satisfaction. Our approach is that the institution contains one or more staff agents in charge of the adaptation (*Adaptation Managers*[6]). These staff agents reason following these transition functions given the observations and goals, and induce the changes in the institution according to the decided adaptation measure. We define two different transition functions depending on what they can adapt [7]. Afterwards, rules (NS') of best GA individuals are stored in a Case-Based Reasoning (CBR) system, which substitutes function ν. All of them receive a set of observed properties (P) and their expected values (e.g., institutional goal G). These properties can be any attribute related to the agents, environment or institution (see section 3.1).

$$\nu : \mathbb{P} \times \mathbb{G} \times \mathbb{NS} \rightarrow \mathbb{NS}$$
$$\psi : \mathbb{P} \times \mathbb{G} \times \mathbb{PS} \rightarrow \mathbb{PS}$$

- *Normative Structure adaptation* (ν): it is a function in charge of updating rules (NS) if current observed properties (P) differ from expected values (G).

[6] The distribution of the adaptation mechanism is out of the scope of this paper. Nonetheless, we think it would have two main axis: task decomposition (e.g. having an agent in charge of each adaptable norm or scene) and goal decomposition (e.g. distributed planning).

[7] Although this paper takes a formal approach, in a related work with a similar scenario [8], we study how these transition functions can be learnt if it is not possible to define them in advance. There, we apply a Genetic Algorithm (GA) technique to evaluate goal satisfaction with specific rules (NS) when a given agent population participates in an institution.

In our traffic example, fines increase if there are a lot of traffic violations. That is, *normative structure* (NS) will be updated (NS'), by increasing the fine parameter (e.g., from 5 to 10) of rule r_a (see section 3.2):

$$
\begin{aligned}
NS \;&= \langle\, S, R = \{r_a\} \,\rangle \\
&r_a : \mathit{utt}\,(\, inform(x, \mathit{policeman}, y, \mathit{car}, \mathit{noStop}(Tlight), t_i)\,) \\
&\qquad \Rightarrow \mathit{add}\,(\, \mathit{obl}\,(\, inform(x, \mathit{policeman}, y, \mathit{car}, fine(\mathbf{5}), t_{i+1})\,)\,) \\
NS' &= \langle\, S, R' = \{r'_a\} \,\rangle \\
&r'_a : \mathit{utt}\,(\, inform(x, \mathit{policeman}, y, \mathit{car}, \mathit{noStop}(Tlight), t_i)\,) \\
&\qquad \Rightarrow \mathit{add}\,(\, \mathit{obl}\,(\, inform(x, \mathit{policeman}, y, \mathit{car}, fine(\mathbf{10}), t_{i+1})\,)\,)
\end{aligned}
$$

– *Performative Structure adaptation* (ψ): it is a function in charge of updating protocols and/or role flows (PS) if current observed properties (P) differ from expected values (G). For example, a possible PS adaptation is to update the number of agents playing a given role allowed in a certain scene (see section 2.2). Thus, in our traffic scenario, if there are a lot of accidents, function ψ would change the number of allowed policemen deployed in our 'Crossroads' scene.

5 Related work

Multi-Agent System (MAS) approaches can be viewed [3][5] as *agent centred* or *organisation centred*. In general, previous work follows an *agent centred* approach [4]. However, the aim of this paper is to study two common individual agent properties —situatedness and adaptation— at an organisation level. In order to do it, we extend the notion of *Electronic Institution* (EI), which already is an *organisation centred* MAS. The closest approach —that also uses an organisational approach— is $\mathcal{S}$-$\mathcal{M}$OISE$^+$ [13]. It provides a mechanism similar to EI *Governors* called *OrgBox*. Hence, each agent uses its own *OrgBox* to communicate with *OrgManager*. This *OrgManager* only changes the *Organisational Entity* state if *OrgBox* petition does not violate any organisational constraint. Thus, we can establish several equivalences with EIs: *OrgManagers* are equivalent to *Scene Managers*; *Organisational Entity* states can be mapped into EI's *Information Model*; and organisational constraints correspond to our *scene* protocols. In a recent work [14] they add a normative layer over $\mathcal{S}$-$\mathcal{M}$OISE$^+$ called $\mathcal{S}$YNAI. Instead of extending original organisational framework with a new component —like EI's *Normative Structure*—, they conceive a *Global Normative Organisation* composed by two organisations: a domain one —the original organisation— plus a supervision one —a new organisation to supervise the original one—. And all supervision organisation roles have *authority* to control domain organisation roles. Hence, they reuse mechanisms they already had defined instead of adding new ones. Given $\mathcal{M}$OISE-EI similarity, applying SEI and AEI's extensions to $\mathcal{M}$OISE seems feasible.

Regarding the concept of *situatedness* at organisation level, most of literature interprets it as providing a location notion to MAS participants. This idea was introduced by Weyns et. al. [15] as a way to allow local synchronisation of agents in the first *Situated MAS* approach [16]. The key point is to restrict participants' perceptions depending on their virtual location. CArtAgO [17] is also an example of this *perception paradigm*. It provides direct interaction among agents, and also indirect interaction through *artifacts*. But, in both cases, the scope of these interactions are limited to *workspaces* where these elements are located. It uses an *agent body* to situate an agent inside those *workspaces*; then its location determines which *artifacts* can be perceived or manipulated by its corresponding agent. In this sense, EI's *scenes* can be regarded as a way of grouping agents that can interact together, which and be interpreted as a virtual location that restricts their perception. *EASI* model [18] goes a step further, and additionally let agents determine which element they want to perceive. They sustain this approach exposing that *awareness* is an active state. Precisely, we see EI's *situatedness* as an *awareness* of the *world* where it is situated. A SEI as a whole, determines its *world* perception and interaction. A first approach to this EI's *situatedness* was the *Simulator Bridge* [6]. However, we go further by assuming all external agents' interactions are performed in the *world*. A similar approach is detailed in [19], where they explore the idea of controlling physical entities with a MAS. They perform a global overview, without detailing changes in EIs, but provide additional ideas like *augmentation* —providing extra information— of real world elements to MAS agents.

Finally, adaptation has been usually envisioned as an agent capability where agents learn how to reorganise themselves. Thus, most works explore agent adaptation driven by individual goals. For instance, Sen an Airiau [20] study the emergence of social norms via learning from interaction experiences. The closest approach to our proposal can be found in the work by Lopez-y-Lopez et al. [21]. Their agents can decide its commitment to obey norms in order to achieve associated institutional goals. In contrast, in our *Autonomic Electronic Institution* (AEI) is the organisation the one adapting itself.

6 Conclusions and Future work

In this paper, we focus on defining adaptation and situatedness for Electronic Institutions (EI). This brings two separated agent properties to an organisational level, or, in other words, we bring up individual level capacities to global —or system— capabilities. As we have seen, we can extend EIs separately: *Autonomic Electronic Institutions* —described in section 4— include adaptation whereas *Situated Electronic Institutions* —in section 3— incorporate situatedness. Nevertheless, since both capacities are compatible, it is also possible to extend EIs with both of them simultaneously. This yields to the concept of *Situ-*

ated Autonomic Electronic Institution (SAEI) which incorporates all previously defined elements[8].

We described —in section 3— how an EI can be situated over an existing social system to try to regulate it with previously defined conventions. Moreover, we also suggested —in section 4— how its adaptation capacity may be used to update such original conventions depending on institutional goals. Thus, a SAEI can be used as a tool to analyse an existing social system behaviour, and autonomously decide to modify its agent coordination to enhance its performance upon a certain defined goals. Accordingly, we see a SAEI as an adaptive *coordination support* layer for social systems with two instruments: (1) supervision of social conventions and (2) adaptation of these conventions, both to enhance agent coordination, and thus, overall performance.

As future work, we envision the institution having another *coordination support* instrument: to provide assistance to its participants in form of *suggestions*. These *suggestions* would be indications about what participants should do during their interactions. Thus, for example, if an agent is trying to perform an action that is not currently allowed, suggestions may inform about those violated restrictions it is not taking into consideration that are preventing it to do the action. This mechanism would also contribute to improve agent *coordination* to enhance global performance. We also plan to include artifacts in the real world, like *intelligent objects* —objects with delegated control capacities [22]— to support this *suggestion* mechanism in situated institutions.

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[8] $SAEI = \langle DF', DC, B, G, TF \rangle$, $DF'\&B$ are described in section 3, DC is explained in section 2 and $G\&TF$ are defined in section 4.

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