Virtual Enterprise Normative Framework Within Electronic Institutions

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Abstract. Virtual Enterprises are a major trend within the B2B scenario. Technological support towards enabling this cooperation model includes the multi-agent systems paradigm. In this paper we identify requirements of Virtual Enterprise contracts, developing a normative framework for contract validation and enforcement. Furthermore, we enclose this conception within the structure of an Electronic Institution, which governs and supports the interaction of agents in business scenarios, providing specific services such as brokering, reputation, negotiation mediation, and contract related services. We focus on electronic contracting as a means of establishing cooperation agreements, and we describe the institution's role on the e-contracting life-cycle.

1 Introduction

Virtual Enterprises are a major trend in cooperative business. Specialization and flexibility are some of the key aspects of an every day more dynamic and global market. The concept of Virtual Enterprise has been applied to many forms of cooperative business relations, like outsourcing, supply chains, or temporary consortiums. We approach this latter case, since it clearly addresses the demand for flexible and dynamic arrangements between different enterprises. We also find it convenient to relate the constitution of Virtual Enterprises to legislation on consortium contracts [20], which regulates the coordination of efforts between enterprises towards accomplishing some activity, where each participant maintains its own core business, while aligning it with other members' activities.

Technological support to the creation of such relationships is arising in many forms. The most ambitious ones intend to automate (part of) the process of creation and operation of Virtual Enterprises, mainly through multi-agent technology approaches, where each agent can represent each of the different enterprises. In fact, research on multi-agent technology addresses issues that fit the Virtual Enterprise scenario. Agents are autonomous, interact with other agents, and enable approaching inherently distributed problems with negotiation and coordination capabilities.

In this paper we develop on the application of multi-agent systems to the Virtual Enterprise lifecycle, by conceptualizing the more general framework of an Electronic

Institution (improving on [23]), which provides assistance to the automated specification of business agreements. The institution represents a normative system that establishes a level of trust enabling the interaction of heterogeneous, independently developed and privately owned agents. We are particularly interested in formalizing business relationships through electronic contracts, and specifically in designing and exploring e-contracts representing Virtual Enterprise configurations.

Therefore, we identify requirements for a contract formalizing the Virtual Enterprise constitution. We then distinguish operational contracts that can be achieved inside this cooperation agreement. Following a normative agent perspective, we suggest the organization of norms in three hierarchical levels of abstraction: (i) institutional norms, used to validate the creation of virtual enterprise contracts; (ii) constitutional norms, expressing the cooperation agreement and used to impose and check the compliance of operational contracts; and (iii) operational norms, which can be monitored and enforced during the Virtual Enterprise activity.

This paper is organized as follows. Section 2 addresses the Virtual Enterprise concept and its lifecycle, bringing to discussion the notion of consortium contracts. In section 3 we develop the Electronic Institution framework, detailing its regulations and services. We then examine, in section 4, the problem of formalizing electronic contracts from a normative perspective, relating contract handling to institutional services; we also identify requirements of a Virtual Enterprise contract. In section 5 we develop a normative framework comprising the institution, the Virtual Enterprise and its operation, and we propose a specification for contracts focusing on the underlying cooperation commitment. We conclude in section 6 describing our current efforts and related work.

2 Virtual Enterprises

The shift, in the last decades, from an industrial economy (based on mass production models) to an information economy associated to the globalization of markets has brought an enormous increase in competitiveness, leading to the need for new organizational models. Enterprise cooperation models have emerged, where different enterprises coordinate the necessary means to accomplish shared activities or reach common goals. This association of strengths enables enterprises to build privileged relationships, based on an increase of advantages through resource and competence sharing, and risk minimization.

Cooperation arrangements are particularly relevant in small and medium enterprises (SME), due to their reduced size and high specialization and flexibility. These kinds of enterprises have been adopting new strategies that enable them to adapt to a constantly changing market, organizing themselves in strategic partnerships. While allowing themselves to maintain their business independence, partners are able to reach otherwise unreachable (physical and customer) markets and to take advantage of economies of scale. Furthermore, many large companies are isolating parts of their businesses, making them autonomous in order to increase the overall flexibility and achieve greater performances. Outsourcing models are also becoming dominant, enabling enterprises to concentrate on their core competencies.

Thus, there is an increasing emphasis in cooperation and coordination of small business units.

The concept of a *Virtual Enterprise (VE)* arose from this trend, and has been defined as "a temporary consortium of autonomous, diverse and possibly geographically dispersed organizations that pool their resources to meet short-term objectives and exploit fast-changing market trends" [6]. We distinguish a VE from a mere tight integration of two business entities in outsourcing (e.g. [15]) or supply chain configurations. In these cases, information technology approaches are focused on managing inter-organizational workflows, providing a fine-grained cooperation between the parties, which in turn tends to the establishment of middle- or long-term relationships. Our conceptualization demands for a greater flexibility, as explicitly stated in the definition presented above.

We associate the creation of a VE to the concept of a *consortium contract*, which is present in the Portuguese legislation [20]. A consortium is a contract according to which two or more entities coordinate their efforts towards accomplishing some activity. This may include the execution of an enterprise (a common example is a civil construction project, like a bridge), the supply of equal or complementary goods produced by the consortium's members to third parties, or the production of goods that can be split amongst the consortium's members. With the creation of a consortium, a new entity can be formed that represents this joint activity to third parties – the consortium is said to be *external*. In other cases, an *internal* consortium can be created, namely when its goal does not include the supply of goods to third parties (although the members' goals might).

The lifecycle of a VE has been studied by some researchers. A simple macro-model that fits our VE conceptualization might include the following stages: *business definition*, *formation*, *operation*, *regulation*, and *dissolution*. Operation and regulation are interleaved phases that go on while the VE exists. The creation of the VE starts with the definition of the business to be developed; this process may initiate because of a client need or because of a market opportunity detected by an enterprise. The formation phase typically includes the definition of goals, the selection of participants through negotiation, and the definition of their roles and respective obligations. The electronic market architecture reported in [21], which this work improves upon, considers a market agent that exists to establish the need (that is, the product or service to be delivered by the VE), and to coordinate the negotiation process in the VE formation phase.

In the operation phase the participants develop the intended business, which may comprise the search for customers (if they are not pre-determined) and the carrying out of activities involved with business enactment. VE adjustments can take place at the regulation phase, when unexpected events occur, making members leave the VE and creating the need for new partners in order to accomplish the established goals. Rules determining how this process is achieved are normally settled at the formation phase. When members verify that the VE has fully accomplished its goals, or decide that it is no longer justified, the VE is dissolved.

There have been lately many research efforts towards infrastructures supporting the VE model. A promising approach is the area of multi-agent systems, which naturally address a number of characteristics in the VE domain, namely their distributed nature,

with autonomous enterprises, and the need for coordination and distributed problem solving. Autonomous agents can represent the individual interests of different enterprises and negotiate in order to constitute a VE. They can then cooperate by coordinating their activities in order to fulfill the virtual enterprise's purpose. Approaches to the establishment of VEs through multi-agent negotiation can be found in [21].

3   Electronic Institutions

Interactions between members of a society are regulated by institutions. These institutions define the rules of the game, stating what is forbidden and permitted to the individuals and in what conditions [9]. An *Electronic Institution (EI)* will be the electronic counterpart of such an institution, imposing regulations on electronic members (agents) that adhere to this electronic society. In particular, an EI will rule the interaction between electronic parties engaged in business transactions, providing an environment where regulated agent interactions can take place. One of the main roles of such an environment is to provide the necessary level of trust that enables agents from different sources to safely engage in business interactions.
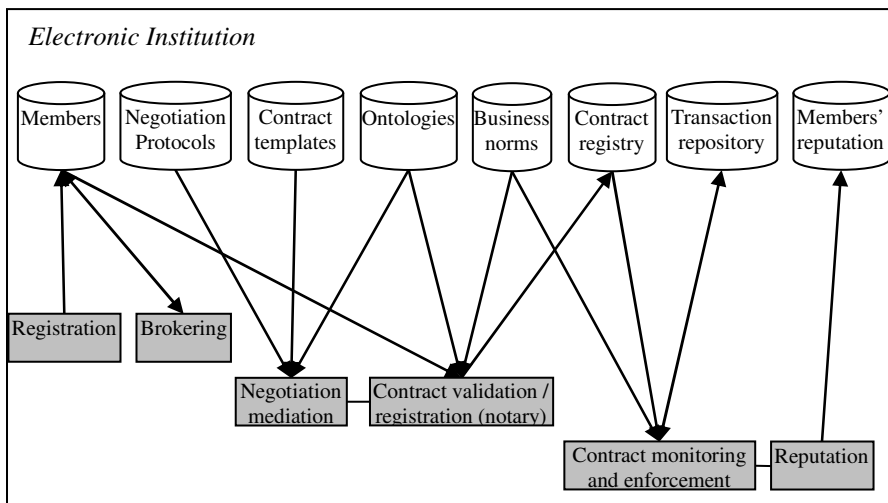

Fig. 1. Regulations and services of an Electronic Institution

First of all, an EI provides a normative system of reference under which agents reach cooperation agreements. When adhering to the institution, an agent abides to a set of imperative norms that regulate and support interactions taking place within the EI. Since the formalization of business relationships (through electronic contracts) are of primary importance, specific regulations on this matter are included as well. The imposed normative system is composed of regulations on the following:

- *Identity of members*: agents must be identified in order to engage in interactions within the EI; also, the signatures of agents when signing contracts must be validated by the institution;
- *Shared ontology specifications*: agents must be able to use the same ontological commitments, so that they can successfully interact, especially in business engagements; the specifications may include both domain-independent business terms and domain-dependent vocabulary;
- *Interaction and negotiation protocols*: the EI may assist the interaction process, imposing a set of well-defined protocols; this is particularly relevant when business relations are created through a process of negotiation, that may require mediation;
- *General business norms*: these are norms applicable to any business engagement, establishing trust by ensuring that certain behaviors are expected and will be enforced;
- *Contract specification*: contracts must be specified according to pre-established directives.

Based on these regulations, the EI also provides support towards facilitating business cooperation between its members. We are particularly interested in mechanisms that enable electronic contract specification and enforcement. In [23] an EI sketch is presented, aiming at supporting the VE lifecycle. Refining that model, we distinguish a set of services that adherent agents can benefit from:

- *Registration*: a service that enables agents to register in the EI, granting them access to the remaining services;
- *Brokering*: yellow-pages support, enabling agents to easily find potential partners;
- *Contract templates*: pre-formatted contracts that boost the formalization of typical business relations, while assuring conformance to contract specification regulations;
- *Negotiation mediation*: using predefined protocols, the EI can act as an intermediary in the negotiation process, taking advantage of template structures and ensuring that resulting contracts are in accordance to business norms;
- *Contract validation*: contracts obtained by two or more parties (and namely not constructed using templates or institutional mediation) can be validated towards the general norms, ensuring that they comply with the overall regulations of the community;
- *Notary*: contract registry services are provided to store consummated (signed) contracts, ensuring their legal existence;
- *Contract monitoring and enforcement*: mechanisms that monitor and enforce the execution of contracts according to their clauses and general institutional norms, registering the fulfillment of transactions and applying predicted non-conformance sanctions;
- *Reputation mechanisms*: these ensure that errant behavior will have a negative impact on an agent's reputation, thus discouraging it.

These regulations and services are depicted in figure 1.

The formation of Virtual Enterprises is an intricate process that typically requires some pre-existing enterprise pool – a *cluster* of enterprises. A cluster has also been

referred to as a "breeding" or "nesting" environment [2], where members share some common elements that make cooperation arrangements feasible (be it technologies, business-related resources, etc.). Advances in information and communication technologies make it possible to support cluster formation. In particular, the Electronic Institution concept permits essential elements when establishing VEs, such as mutual trust building, common ontologies and standard business practices.

4   B2B E-Contracts

In B2B electronic commerce, more attention has been given recently to contract formation and fulfillment. In fact, this issue is part of the so-called B2B transaction model, as presented in [14]. Approaches to B2B contract handling (e.g. [13]) identify the need to specify and represent contracts, and further to monitor and enforce them.

Contracts can have different forms, representing business agreements ranging from simple deals used to exchange resources (such as in purchasing a product), to complex business relationships between parties. However, most of the research literature devoted to e-contract automation simplifies contracts to the former type, defining one time relationships between a customer and a seller. Little attention has been given to contracts that result from a Virtual Enterprise formation process (an exception might be [22]). These contracts are more complex in the sense that they need to specify how several involved parties should behave, during a period of time, in order to participate in a cooperation effort towards a common goal.

4.1   E-Contracts and Norms

Contracts are formalizations of the behavior of a group of agents that jointly agree on a specific business activity. Contracts are used as a means of securing transactions between the involved parties, forming a normative structure that explicitly expresses their behaviors' interdependencies. *Electronic contracts* are virtual representations of such contracts. The aim of e-contracting is to improve the efficiency of contracting processes, supporting an increasing automation of both e-contract construction (using automated tools) and execution (integrating with business processes). Within our framework, e-contracts will be obtained by agents representing different enterprises, meeting inside the EI to which they adhered.

The components of a contract include the identification of participants, the specification of products and/or services included and a discrimination of actions to be performed by each participant. These actions are usually accompanied with time and precedence constraints. Typified business relations can recurrently use pre-formatted contracts. In this case, contracts usually have a set of identified *roles* to be fulfilled by the parties involved in the relation.

The core of a contract is composed of contract clauses. These clauses can specify different types of behavior *norms* that will guide the interaction between the parties. Broadly speaking, three types of norms can exist within a contract structure:

- *obligation*: an agent has an obligation towards another agent to bring about a certain state of affairs (by executing some action), before a certain deadline;
- *permission*: an agent is allowed to execute some action, within a given window of opportunity (specified either by a deadline or more generally by a state of affairs);
- *prohibition*: an agent is forbidden to bring about a certain state of affairs (some action is interdicted).

A formal approach to model such norms is *deontic logic* [27] (also known as the logic of normative concepts), a branch of modal logic. The normative concepts obligation, permission and prohibition are analogous to the modal concepts of necessity, possibility and impossibility, respectively.

When representing contracts, another fundamental concept is typically added to the norms above: the *sanction*. Any obligation must be accompanied by at least one sanction, as obligations without sanctions are ineffective [17]. Thus, obligations are not absolute, but relative to their associated sanctions in case of non-performance [24]. Prohibitions can be addressed in an analogous way. A prohibition is sometimes handled as a negated obligation, that is, a duty for not performing some action (see, for instance, [17]).

Approaches to the automation of contractual relationships necessarily include this sanction component. Particularly when that automation is based on the autonomous agent paradigm, norms cannot be taken as constraints on the behavior of each contractual party.[1] Each agent is able to deliberatively reason about its goals and the norms it has committed to (hence the notion, in [3], of *deliberative normative agents*). An agent can violate a norm in order to accomplish a private goal that it considers to be more important. When doing so, the agent is aware of the sanction it will be subject to.

Norms and Electronic Institutions. Contracting is normally subject to contract law. This law is enforced by the court, and can be seen as a normative system that contracts must abide to. Generally speaking, we can thus say that a contractual relationship will have a normative system of reference (enforced by an institution), according to which the contract will be built, detailing the interactions that will take place between the parties. The relation between the contract and the normative system is hierarchical, meaning that the contract can inherit norms from the normative system already established, using it as a ground basis.

Electronic institutions, while regulating the interactions that can take place between agents, can represent normative systems that limit the behavior of participants and describe the penalties incurred when norms are violated. Contractual relations created inside the institution must abide to the imposed norms, specifying the details of a particular business relation.

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[1] Although most initial research on norms in multi-agent systems has focused on norms as constraints on behavior via social laws. Agents were not allowed to deviate from these laws, which were used to ensure cooperation between interacting autonomous selfish agents.

4.2   E-Contract Handling

Any contractual relationship can be said to evolve through a number of steps. These can be resumed to the following three stages [28]:

- *information discovery*: clients find potential suppliers;
- *contract negotiation*: the parties negotiate the contract terms – the result of this stage is a legally binding contract, reflecting the agreement made;
- *execution*: the contract terms are fulfilled by the parties, namely involving product delivery or service rendering, and the corresponding payments.

The first stage thus comprises the brokering phase of B2B electronic commerce. One can also conceptualize it as a *pre-contractual phase*, involving a definition of the products or services sought/sold by clients/suppliers, and the utilization of yellow-pages services allowing potential partners to contact each other. The second stage is devoted to the negotiation of the terms of an agreement – it is the *contractual phase*, since a contract is being constructed. That agreement will express a number of steps to be performed by the contractual parties. Hence, the parties negotiate not only attributes of products/services but also details of how those products/services will be delivered/rendered and paid. The document that represents the agreement reached is a legally binding contract, signed by those involved. Typically, it will also specify how to handle exception conditions, such as those related with non-fulfillment of duties (e.g. late delivery or non-payment). The third stage is the *post-contractual phase*, that is, after the contract is established it is time to proceed as agreed. It is also referred to as the *fulfillment* phase. In more complex and integrated interactions, the parties involved will eventually engage their business processes, forming an inter-enterprise workflow.

E-contracts are achieved inside controlled environments – Electronic Institutions – that establish certain rules of behavior to be followed by its members, ensuring a level of trust that is crucial to the interaction of heterogeneous, independently developed and privately owned agents. The three stages presented above are supported by the Electronic Institution framework as follows.

Information discovery assistance is a typical function of electronic markets in general, but in the VE case special care can be given to the process of finding potential strategic business partners, with appropriately tailored services. Cooperative business relationships may involve more than the supply of merchandise, requiring a tighter cooperation between the parties involved. Therefore, more attention is needed in the partner selection phase.

The contract negotiation phase is assisted through contract template availability, negotiation mediation services (such as those presented in [21]), and norm conformance checking, allowing only legal and enforceable contracts to be formed. Several researchers acknowledge the need for a starting ground in contracting (see, for instance, [28], [17], and [24]). In fact, starting a negotiation where nothing is fixed represents a too ill-structured problem to consider automating. The importance of a contract template resides on its ability to provide a structure on which negotiation can be based. Furthermore, certain kinds of business relations are formally typified (for

instance, sales and purchases). In this sense, instead of beginning from scratch a new contractual relation, two (or more) agents can use an electronic contract template, which is a contract outline containing domain-independent interaction schemata and variable elements (such as price, quantity, deadlines, and so on) to be filled-in with domain-specific data resulting from a negotiation [17]. If all goes well, the result of the negotiation will be an actual contract, instantiated from the template, which will be signed by the parties. Templates thus provide a structure that allows negotiation, as a process of cooperative construction of a business relation, to be focused on those elements that, when instantiated, will distinguish the agreement obtained from other contractual relationships. Meanwhile, the common elements in relations of the same type will be preserved. These common elements might include, for example, outline commitments of the involved parties, which when instantiated through negotiation will detail their concrete objects (eventually including technical properties) and temporal references.

Contract execution is enforced by appropriate monitoring services, which register transactions and deal with non-fulfillment situations. The execution of an e-contract consists on the parties following the norms they committed to when signing the contract. If any deviations from the prescribed behavior should occur, sanctions can be applied as specified in the contract or in its normative system of reference. However, the parties involved will typically not voluntarily submit themselves to such penalties. Therefore, appropriate mechanisms to monitor and enforce norm execution are needed. Only a trusted third party (the EI) can enable the necessary level of confidence between the parties involved in a business relation. The verification of real-world contracts is often dependent on external (physical world) entities, which must interface with the EI to allow the automation of the process.

4.3 Requirements of a Virtual Enterprise Contract

A normative conception of contracts is normally used for contract representation. Hence, general languages for representing norms in contracts have been proposed (e.g. [17], [24], and [8]). However, little research is devoted to the representation of VE contracts.

Normative Statements. Based on the operators of deontic logic, normative statements can be formally represented as [24]:

$$\text{ns: } \varphi \rightarrow \theta_{s,b} \, (\alpha < \psi)$$

where

> ns is a label
> φ is an activation condition
> θ is a deontic operator (obligation, permission, or prohibition)
> s is the subject of θ
> b is the beneficiary of θ
> α is the action to perform or the state of affairs to bring about
> ψ is a deadline

In this approach, obligations are not absolute, but relative to their associated sanctions. That is, deviation from prescribed behavior is admitted and properly addressed through sanctions. These are defined just like the other normative statements, but by specifying the non-fulfillment of a given obligation as the activation condition. Sanctions may give rise to other obligations or prohibitions: either the beneficiary of the violated norm is granted a right (the subject has a new obligation towards the beneficiary) or the subject of the violated norm is refused a right (he is forbidden to do something).

This representation of norms allows for the construction of any contract that can be entirely specified using these building blocks. For instance, contracts reflecting simple purchasing operations might be composed of four such norms: (1) a seller's obligation to provide a requested good by a certain deadline; (2) a buyer's obligation to pay by a certain deadline, after receiving the demanded good; (3) a sanction predicting possible non-fulfillment of delivery on the seller's part – e.g. a discount; and (4) a sanction predicting possible late payment on the buyer's side – an interest rate, for example.

Virtual Enterprise Contracts. The contracts we are interested in might also benefit from a group of enhancements that facilitate contract construction. According to our approach, an electronic contract is a formalization of a business agreement that two or more agents, representing different entities, establish as a cooperative business activity.

A VE thus constitutes a complex case of a business agreement, and certain aspects of its nature must be contemplated. Namely, the following list of requirements must be taken into account:

− The contract will represent an ongoing (although limited in duration) relationship between the signatories. This is in contrast to sell/purchase operations, which have a very short-term nature, limited to order-delivery-payment operations (if we disregard possible warranty periods);
− Some interactions between the parties may be continuously repeated. Particularly when the goal of the VE considers the production of goods that are to be supplied to third parties, members exchange resources, production outputs or information in a cyclical manner. The VE (and its formalizing contract) may terminate not by a pre-specified deadline or at the end of a predetermined normative path, but when its members decide to cancel their conjoint operation;
− Support for the exit and entrance of partners has to be given. VE contracts can specify conditions according to which partners may leave or enter the organization. A VE has a flexible structure, allowing for this kind of adjustments to occur, particularly when the involved parties fail to perform their duties. In this case, a member may leave the VE not for its own initiative, but because its behavior imposes an expulsion, possibly with associated indemnities. Nevertheless, the VE's related business can survive with the entrance of new partners;
− When representing a new entity, the VE may establish contracts with third parties, namely customers. The constitution of the VE might regulate the way how these contracts are to be formed;

−   An important aspect of the VE operation is how profits are to be exchanged. That is, the transfer of payments can occur depending on the transfer of (partial) products between the members of the VE, or only when goods are sold to the final customers (assuming that the VE's goal is such). In the latter case, a party's return on investment depends on the success of the VE, making risk an explicit factor to consider when entering the joint venture (which typically implies participation both in profits and losses).

A contract representation language that is convenient to formalize VE agreements should therefore take into account these concerns. VE contracts cannot be constructed just with the normative statement represented above. Richer operators are needed to specify such contracts. We also find it convenient to split the VE contractual formalization in two levels of abstraction: constitutional and operational (see section 5).

Practical requirements also arise when one attempts to automate contract monitoring and enforcement. In particular, contracts must provide directions as to how and when to verify their fulfillment. In the next section we distinguish contracts that can be enforced from contracts than can only be verified on creation. A contract will be enforceable if it is possible to verify if the parties' actions conform to the agreement (this verification may eventually require the utilization of external entities' services). Event-based monitoring systems must be exploited in order to check for contract compliance. Many contractual actions are dependent on deadlines, which require a monitoring system to act in response to defined timers [19]. This mixed event and time-based approach allows for checking both if occurring actions are in accordance to the contract and if missing actions are in violation of obligations.

5   Virtual Enterprise Normative Framework

In this section we propose a hierarchical organization of norms, in an environment addressing the establishment and operation of VE contractual relationships.

A VE contract represents a framework within which further interaction between its participants takes place. This will include the establishment of operational settlements (contracts) for the exchange of products/services that implement the desired level of cooperation that led to the formation of the VE in the first place. The VE contract therefore adds a normative layer to the electronic institution's framework. Operational contracts made within the VE constitution must abide to these norms. Figure 2 illustrates the hierarchical relationship between three levels of norms: *institutional*, *constitutional* and *operational*.

According to this model, it is important to distinguish between *verifiability* and *enforceability*. Institutional norms provide a framework against which a VE contract can be validated. Accordingly, this VE cooperation agreement establishes a platform of cooperation within which operational contracts between VE participants can be checked. However, only operational contracts will be enforceable, in the sense that only these contracts specify the concrete interactions that must take place between some of the agents participating in the VE. The verification (validation) of contracts occurs when contracts are created, whereas their monitoring and enforcement takes

place at the execution stage. We take a passive perspective on the verification of contracts – the institution will react to the creation of a new contract – and an active one on the enforcement of contracts – the institution will proactively check the fulfillment of contractual norms.
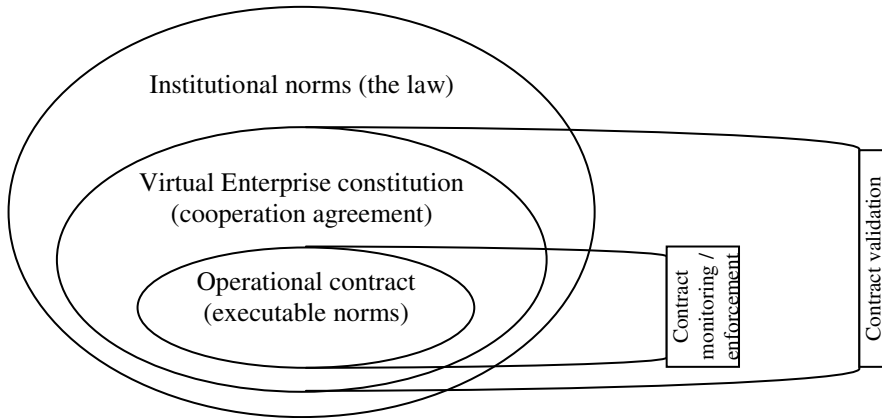

Fig. 2. Normative framework

Besides providing a layer according to which operational contracts are validated, another important role of the VE constitutional contract is to specify the conditions that participants *must* accept when establishing operational contracts. When adhering to the constitution of a given VE, agents impose themselves a level of cooperation that is then reflected in the terms of executable contracts. The non-acceptance of such terms should be sanctioned, ultimately by the expulsion from the VE.

5.1 Institutional Norms

Institutional norms include regulations on general contracting activities and on consortium contracts in particular, as well as default rules to resolve any issues that have not been explicitly addressed by the parties. These two groups of regulations influence the formation of both VE constitutional contracts and operational contracts.

Contract law theory [4] identifies two roles for default rules. On one hand, they can be used to be left in place, that is, they can specify default values that the parties would agree on, with the intent of minimizing contracting effort. On the other hand, certain default rules can intentionally provide unfavorable default values, forcing contractual parties to explicitly deal with specific contract clauses, making sure that every participant is aware of the agreed values. Another use of this latter case is to make contractual parties fill in certain formalities in their contract, without which the contract would not be valid or enforceable.

One possible way to guarantee that parties deal with specific contract details is through the use of institutionally provided *contract templates*. These may contain predefined values as well as un-instantiated (negotiable) parts.

Since different contractual relations can have a lot in common, contracts (and templates) can be underspecified, relying instead on institutional norms to complete the overall picture. These norms include default values for certain contractual issues (e.g. a 5 days deadline for any payment after delivery), and imposed regulations concerning exceptional contract execution situations (though not necessarily contract violations).

Regarding consortium contracts, examples (inspired in [20]) of institutional regulations include general rules about how a consortium contract may be modified, conditions according to which an agent can exonerate himself from the contract, rescind situations towards a non-compliant member, and consortium ending settings. Also, according to the consortium's nature, regulations on the split of externally received payments or profit share policies can be defined.

As figure 2 suggests, we aim at providing a normative background that can be computationally exploited in validating, monitoring and enforcing contracts.

5.2 Virtual Enterprise Constitutional Norms

Depending on the type of VE created (see consortium goals and types in section 2), different kinds of norms can be included in the VE contract. However, some common elements include:

- Duration: specifically, a starting date for the VE operation and ending conditions;
- Membership: rules for the exit of partners and the entrance of new ones;
- Cooperation terms: demanded workload for each partner, agreed prices for each partners' contribution, and workflow process general outline.

In the case of a consortium with the goal of selling the result of the cooperation effort to third parties, the VE contract might also regulate issues on profit exchange and on the creation of contracts that represent such selling activity.

VE Contract Specification. Focusing on the cooperation commitment that parties impose themselves when establishing a VE contract, we consider the following contract structure:

$$VEContract = <H, CoopEff, BP>$$

- *Header (H)*: identifies the contract and its normative system of reference, introduces the organization participants and the resources (products, services, payments, etc.) that are to be exchanged between them, specifies a signing date and includes the parties' digital signatures;

$$H = <Id, NormSys, Partics, Ress, Date, Signs>$$
$$Partics = \{Partic_i\}$$
$$Ress = \{Res_k\}$$
$$Signs = \{Sign_i\}$$

- *Cooperation effort (CoopEff)*: indicates workload acceptance levels and associated prices for each of the participating agents; these are obtained from the negotiation process, as described in [21];

$$CoopEff = \{<Partic_i, Res_k, Wload>\}$$
$$Wload = <MinQt, MaxQt, Freq, UnitPr>$$
$$Freq \in \{per\_day, per\_week, per\_month, per\_year\}$$

- *Business process (BP)*: describes the flow of resources between participants, in the form of *request permits* indicating allowed requests that parties may perform towards their partners; these requests activate *obligation chains* (sequences of obligations where each one is dependent on the fulfillment of the previous one) that implement the business transaction steps composing the required workflow.

$$BP = <\{ReqPerm_m\}, \{OblChain_n\}>$$
$$ReqPerm = <Who, Whom, What>$$
$$Who, Whom \in Partics; \ What \in Ress; \ <Whom, What, \_> \in CoopEff$$
$$OblChain = <OblRule_1, OblRule_2, …, OblRule_p>$$
$$OblRule = <ActCond, Obl>$$

According to this layout, we regard request permits as permissions (rights) granted to agents for demanding the contribution of the envisaged agent, bounded by the cooperation effort that it committed to. The enactment of such permission activates an obligation chain describing the procedures to carry out. Making these obligations dependent on requests relieves us from pre-specifying the exact dates when all the exchanges should occur, which is difficult to evaluate and subject to contingencies.

The workload acceptance levels (together with their agreed prices) include both a minimum desired production output (under which a partner's participation may not be profitable anymore) and a maximum committed contribution to the organization (over which the partner is not compromised to assure). We intend to exploit these ranges when checking the conformance of agents to their contractual cooperation promises, and when evaluating conditions for contract exoneration.

The VE contract structure should become more complex as we introduce more elements such as sanctions, contract duration, and membership rules. However, these additional elements can just as well be defined as default regulations at the institutional level, keeping the contract contents focused on the essential. The core of a specific cooperation agreement can be captured by the above structure.

5.3 Operational Norms

Contracts representing concrete exchange of products/services will include specific actions to be performed by each of the contractual parties, which must be members of the VE. These contracts implement the VE cooperation agreement, representing the workflow processes outlined in the VE constitutional contract.

Norms present in such contracts consist of obligations related to delivery and payment of such products/services. At this level, contracts may be composed of normative statements as approached in [24] and discussed in section 4.3. The degree of detail of such norms will determine the possibility for monitoring and enforcement of operational contracts.

According to the specification above on VE contracts, operational norms become active when a request is made by an agent concerning the exchange of resources

between consortium's participants. The obligation chain indicates actions to be performed by the involved parties, being amenable to institutional monitoring activities based on a business transaction repository.

We can regard the constitutionally predicted obligation chains as templates for operational norms that are instantiated, by the enactment of requests, with specific data depending on the chain scope, such as dates and quantities.

6   Current and Related Work

We are refining our Electronic Institution's model depicted in figure 1, developing a computational framework for facilitating multi-agent contracting in Virtual Enterprise scenarios, and for monitoring contract execution. We develop on [21], where an advanced negotiation protocol is presented, specifically tailored to handle the formation of Virtual Enterprises, and on [23], where a simplified model of an EI is sketched to support the VE lifecycle.

We are applying our efforts on the specification of a representation formalism that allows us to model institutional norms and to represent both constitutional and operational contracts. This representation should allow the validation of contracts (according to the normative framework presented in the previous section), as well as the enforcement of operational contracts and their monitoring. In particular, we are defining an XML schema for specifying VE contracts, according to the structure briefly presented in section 5.2; this will be used to provide contract negotiation support tools. A promising approach towards norm representation and verification is the use of a rule-based inference engine (e.g. JESS, as used in [11]), which allows for a declarative representation and thus facilitates norm updating, both from the creation of new contracts and from institutional norm evolution (see future work below).

Since it is impossible to computationally force an agent to fulfill an obligation, we envisage the effect of triggering sanctions not only as introducing new obligations, but also as disabling certain agent actions while within the institution (prohibitions, in normative jargon). This appears to be the approach taken in [9], with the concept of *normative rules*.

Contract law [4] includes some essential elements that we have adopted. The essence of contract is commitment: the assurance that others will, when the time comes, uphold their end of a bargain. Whereas in some situations reputation mechanisms can provide that assurance, contracting offers an additional recourse when these "non-legal sanctions" are insufficient to constrain opportunism: parties expose themselves to legal sanctions for non-fulfillment of duties. The utilization of default rules, which define the parties' obligations in the absence of any explicit agreement to the contrary, allows resolving issues that have not been explicitly addressed by the parties. Relational contract theory [16] studies continuing relations that are naturally self-enforceable. Instead of a detailed enforceable contract based on a third party, a relational contract is based on repeated interactions and social norms, representing an informal agreement sustained by the value of future relationships. Relational contracts may arise both because of problems in achieving enforceable

contracts and due to the costs of legal enforcement. Although formal contracts seem opposite to relational ones, they may coexist. Contracting parties use a mix of legal and extralegal mechanisms. Formal contracts are preferred when establishing relationships between unknown parties. On the other hand, regular partners generally rely on implicit relationships, supported by trust and by the threat of withholding business from anyone who has broken a promise in the past.

Our model of an EI supports these two contractual paradigms, including both reputation facilities and contract enforcement functionalities. We capture contract law elements by exploiting a hierarchical normative framework where the EI has the central role of establishing common business rules.

There is not much work, to the best of our knowledge, devoted to the formalization of VE contractual agreements. In [22], VE contract establishment is addressed, and the authors distinguish between agreements and contracts. Agreements, composed of framework clauses, are seen as mutually accepted rules of engagement between parties, whereas contracts are agreements with a legally binding weight (and sufficiently specific to be legally enforceable).

Within the multi-agent research community, some researchers address the advantages of anticipating sanctions (also called de-commitment penalties) in multi-agent formal contracting, introducing the concept of a *leveled commitment contract* [25], and study reasoning decision processes that consider strategic breaches [25][12].

The execution of contracts is assisted in [24] with a *contract fulfillment protocol*, a collaborative protocol based on the normative statements' lifecycle. Agents communicate about their intentions on fulfilling contractual norms, allowing partners to know what to expect from them and permitting a fluent and prompt execution of contracts, since agents do not have to wait for the fulfillment of their partners' obligations to start executing their own (hence the collaborative nature). In [19] the authors identify, from a monitoring perspective, requirements for a business contract language. They focus on the time-constrained nature of contractual actions and on event-based monitoring of contracts.

The real-world application of agents in automated contract fulfillment is challenged by the presence of complex legal issues and subjective judgments of agent compliance [14]. Some work on these matters has been made, for instance, in [5], where an e-market controller agent (a third party) is suggested to resolve disputes arising from subjective views on contract compliance, thereby playing the role of a judge. This agent holds a representation of the contract, and when a conflict occurs it collects evidence from the involved parties and obtains information from independent advisors, such as certification authorities, regulators, or controllers of other associated markets.

The study of norms in multi-agent systems is relatively recent. Some pertinent references include [1], [18] and [26]. In [1] the authors distinguish between regulative and constitutive norms, which have not a direct correspondence to our institutional and constitutional normative layers. While their approach differentiates norms according to their nature (regulating behavior vs. describing the legal consequences of actions), ours is mainly concerned with norm scope.

A two-level conception of normative agent interactions is also proposed by others. In [7] the authors model a society of agents distinguishing between an institutional level (where social norms and rules are specified) and an operational level (dependent on the goals of each agent). In [24] two classes of sanctions are suggested: *endogenous sanctions*, which are specified in the contract, and *exogenous sanctions*, which are defined within the normative system to which the contract is subject. The latter are applied when clauses without specified endogenous sanctions are violated.

The *electronic institution* concept has been developed by other researchers, although perhaps with different perspectives. One of the most comprehensive works on the design, specification and development of electronic institutions is ISLANDER [10], together with the AMELI infrastructure [11]. This approach considers dialogical institutions, where agent interaction is made by the utterance of illocutions and is fully specified in a performative structure consisting of scenes and transitions among these scenes. Furthermore, norm compliance is assured through the use of mediator agents called *governors*, preventing norm violation. A questionable limitation of this approach is the lack of autonomy agents are confronted with when entering such an institution. Moreover, since the institution is totally based on the definition of interactions among scenes, it becomes a too rigid model, using norms to restrict behavior and avoiding the need for sanctions. Our model intends to be more open, and addresses the wider perspective of an institution providing support for commitment expression through contracts. These can be negotiated inside the institution, but need not be; enforcement mechanisms are to be in place, based on sanction imposition and reputation, thereby guiding agent behavior (as opposed to restricting agent autonomy).

For future work, we intend to develop mechanisms that allow agents to learn the level of detail they should allow their contracts to include, according to their contractual parties' reputations. Also, the EI itself might impose certain specifications in new contracts signed by those who have previously denoted non-fulfillment of duties.

An open topic we intend to investigate is whether new institutional norms can emerge from the continuous operation of the EI. For instance, the EI can observe that a certain kind of business relationship is becoming common, and thus might benefit from specifically tailored regulations, or from appropriate templates facilitating this cooperation structure.

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