Electronic Institution Platform for B2B Contracting

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LIACC / FEUP
http://paginas.fe.up.pt/~eol/RESEARCH/ei.html
Electronic Institution Platform for B2B Contracting

Introduction
Rationale

• Provide services for B2B process automation
  – Supply-chain, Virtual Enterprise, SMEs...

• Benefits for:
  – Business players
    • Automatic negotiation of business opportunities
    • Trustable environment based on contractual behavior
    • E-contract creation support with well-defined contract clauses
    • Automatic contract monitoring
  – Business platform providers (e.g. online B2B marketplaces)
    • Added-value in provided B2B services
      – Trust, automated contract negotiation, contract monitoring
Research Overview

• Goals:
  – To apply multi-agent systems research to B2B e-sourcing and e-contracting, aiming at process automation
  – To identify agent-based services for Virtual Enterprise formation and operation
  – To design and develop an Electronic Institution platform including such services

• Main research lines:
  – Agent-based automatic negotiation
  – Normative Multi-Agent Systems
  – Computational Trust and Reputation
Automatic Negotiation

- **Negotiation-mediation service**
  - Negotiation protocol for VE partner selection
    - Multi-attribute negotiation with qualitative feedback
    - Information privacy
  - E-contract instantiation
  - Trust-aware contract negotiation

- **Ontology-mapping service**
  - Matching terms using syntactic and semantic measures
  - Enable negotiation between enterprises using different domain ontologies
Normative Environment

- **Normative framework**
  - Hierarchical norm structure with predefined contract clauses
    - Background regulations to facilitate contract establishment
  - Flexible and expansible in order to accommodate new contractual settings

- **Contract monitoring and enforcement**
  - Rule-based monitoring engine
  - Monitoring model that allows cooperation in contract enactment
  - Enforcement through sanctions and reputation

- **Contract model to use in an Electronic Institution**
  - XML Schema
  - E-contracts obtained as an outcome of the negotiation process
  - E-contracts may include further norms
Computational Trust and Reputation

- Computation of confidence scores using:
  - Dynamics of trust
    - Asymmetry, maturity, distinguishably in trust building
  - Contextual fitness
    - How fit is a business partner to a specific business opportunity?
    - Profiling of partners and business opportunities
    - Inference over profiling and contractual information

- Support for trust-aware automatic negotiation

- Trust as an additional enforcement mechanism for social order control
An institutional normative environment includes:
- a flexible and expansible normative framework that facilitates contract establishment
- a contract monitoring service
- enforcement mechanisms

Agent-based automatic negotiation includes:
- negotiation protocols for partner selection
- ontology-mapping tools
- negotiation-mediation service with information privacy
- reputation-aware contract negotiation

A Computational Trust and Reputation (CTR) system that takes into account:
- the dynamics of trust building
- the contextual fitness of business partners to a specific business opportunity
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Agent-based Automated Negotiation
Agent-based Automated Negotiation

• Negotiation protocols
  – Mechanism design: the rules of the negotiation game
  – What can agents do
  – Auctions vs. Negotiation
    • Negotiation: two or more parties jointly determine outcomes of mutual interest
    • Auction: market mechanism with an explicit set of rules determining resource allocation and prices based on bids from market participants

• Negotiation strategies
  – How each agent plays the game
Virtual Enterprise (VE)

- “a cooperation of legally independent enterprises, institutions or individuals which (...) contribute their core competences (...) the cooperation is managed by using feasible information and communication technologies”

- “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”

- “a temporary alliance of enterprises that come together to share skills or core competences and resources in order to better respond to business opportunities, and whose cooperation is supported by computer networks”
Virtual Enterprise (VE)
VE Lifecycle

Identificação

Formação

Operação

Dissolução

Empresa 4

Empresa 5

Empresa 1

Empresa 3

Empresa 2
MAS for VE Formation

• Modeling a VE as a Multi-Agent System (MAS)
  – Distributed and autonomous entities
  – Temporary coalition

• Negotiation methodology for VE formation
  – Multi-attribute and adaptive
  – Distributed dependencies resolution
  – Information privacy
Q-Negotiation

Agente Mercado

- formulação de anúncio
- avaliação de propostas
- formulação de comentário

anúncio

proposta

comentário

múltiplas rondas

pedido

Agente Empresa 1

formulação de proposta, em resposta a anúncio ou comentário

::

Agente Empresa j

- avaliação de propostas
- seleção da proposta vencedora
Q-Negotiation

• Anúncio
  – Efectuado pelo Agente Mercado
  – Especificação do **Bem** (conjunto de componentes)
  – Especificação de um componente pode incluir domínio de valores admissíveis para os atributos (**não especifica função de utilidade**)  

• Formulação da proposta inicial
  – Efectuada pelos Agentes Empresa com competência para satisfazer o(s) componente(s) anunciados
  – A proposta inclui os **valores mais favoráveis** ao Agente Empresa (que satisfaçam o anúncio).
Avaliação da proposta
- Quantifica o desvío dos valores da proposta relativamente aos valores óptimos

\[ A_v = \frac{1}{\text{Desvio}}, \quad \text{Desvio} = \frac{1}{k} \sum_{i=1}^{k} (k - i + 1) \times \text{dif} (\text{Pref}_{V_i}, V_i) \]

Formulação de comentário qualitativo
- É atribuído um valor qualitativo (suficiente, mau, medíocre) a cada um dos atributos que constituem a proposta
- Descreve a distância entre os valores da proposta actual e da melhor proposta recebida até ao momento

 diz que existe uma melhor proposta no mercado é mais convincente que dizer que a proposta actual não é óptima
Q-Negotiation

- Reformulação de uma proposta
  - Usa um algoritmo baseado na aprendizagem-Q
    \[
    Q(e,a) = Q(e,a) + \alpha \left( r + \gamma \max_b Q(e',b) - Q(e,a) \right)
    \]
  - Acções incluídas no espaço de exploração são deduzidas de acordo com o comentário recebido
    - estado: \( e = <c_{l_1}, c_{l_2}, ..., c_{l_k}> \), \( c_{l_i} \): comentário qualitativo relativo ao atributo \( x \)
    - acção: \( a = <a_1, a_2, ..., a_k> \), \( a_x \in \{ \text{incremento}, \text{decremento}, \text{manutenção} \} \)
  - Valor de recompensa é calculado de acordo com o comentário qualitativo recebido (recompensa imediata)
    \[
    r = \begin{cases} 
    k & \text{se vencedor} \\
    k - \frac{1}{2} \sum_i \text{penalidade}_i & \text{se não vencedor} \\
    \end{cases} 
    \quad (0 \leq \text{penalidade}_i \leq 1)
    \]
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Ontology-Mapping
What is Ontology?

• “An ontology defines the basic terms and relations comprising the vocabulary of a topic area as well as the rules for combining terms and relations to define extensions to the vocabulary.”

• “An ontology is an explicit specification of a conceptualization.”

• “An ontology is a formal specification of a shared conceptualization.”

• “An ONTOLOGY may take a variety of forms, but necessarily it will include a vocabulary of terms, and some specification of their meaning. This includes definitions and an indication of how concepts are inter-related which collectively impose a structure on the DOMAIN and constrain the possible interpretations of terms.”
Ontology Building

• Definition of:
  – Classes organized in a taxonomy (subclass-superclass)
  – Properties (attributes)
  – Relations
  – Instances (elements)
  – Axioms
  – Functions

• Representation languages:
  – Frames, RDF(S), OWL, XML Schema, Class hierarchies (e.g. Java)
## Tools for Ontology Building

<table>
<thead>
<tr>
<th>Ontolingua</th>
<th>WebONTO</th>
<th>WebODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protégé</td>
<td>OntoEdit</td>
<td>OilEd</td>
</tr>
<tr>
<td>Apollo</td>
<td>SymOntoX</td>
<td>OntoSaurus</td>
</tr>
<tr>
<td>DagEdit</td>
<td>DOE</td>
<td>IsaViz</td>
</tr>
<tr>
<td>SemTalk</td>
<td>OntoBuilder</td>
<td>DUET</td>
</tr>
</tbody>
</table>
Protégé (http://protege.stanford.edu/)
Protégé (http://protege.stanford.edu/)
Ontology Interoperability Issues

• Mapping
  – **Match** terms and expressions defined in a **source ontology** with terms and expressions defined in a **target ontology**

• Translation
  – To reuse an ontology with a **different tool or language**
  – Tools don’t always support the same ontology formats
Ontology Applications

- Knowledge management
  - Integration of heterogeneous, distributed and semi-structured information resources

- Electronic Commerce
  - Business engagements between different entities (B2B)
  - United Nations Standard of Products and Services Code (UNSPSC): taxonomy organizing products and services
    - facilitates transactions among B2B players that agree with the taxonomy (ontological commitment)
  - Internet sites: organization of content into categories

- Search engines
  - Semantic information retrieval

- Natural language processing
  - Ontologies such as WordNet are used to represent grammatical structures that enable semantic analysis of texts

- Enterprise modeling
  - Ontologies support the organizational memory of the enterprise, allowing its different departments to interoperate with a common vocabulary and well defined rules
Ontology-Mapping: Motivation

• Automating business interactions is not a trivial task
  – Simplifications are typically made regarding the ability of agents to understand each other

• Underlying assumptions regarding agents’ interoperability:
  – common language and interaction protocols
  – common understanding on domain-independent business vocabulary
    • proposal, deal, price
    • delivery, payment
  – common domain ontologies
    • relax this requirement
The Heterogeneity Problem

• Interoperability between different agents
  – hindered by the use of different ontologies
    • with different representation formats
    • with different terminologies for the same concepts
    • with similar terminologies for distinct concepts

• Critical impediment to efficient business information exchange and to the automation of B2B processes

• Avoid heterogeneity problem?
  – common or shared ontology
  – unfeasible in open environments
  – conversion of own ontologies to common one is too troublesome

• Approach
  – an **Ontology Service Agent** for MAS (FIPA proposal)
    • ontology mapping
Agent-Based Automated Contracting

⇒ An ontology-mapping service aligned with a negotiation mediation service
Ontology-Mapping Service

• Principle:
  – two different ontologies for the same domain will probably have concepts with a similar syntax and that share similar attributes

• Assumption:
  – domain ontologies describable in terms of classes and attributes

• Two approaches:
  – **N-Grams**: lexical similarity
    • given two strings, compute the number of common sub-strings
  – **WordNet**: semantic similarity
    • a lexical database with semantic relations between words
N-Grams

• **n-gram**: a sequence of *n* characters, where *n* is a parameter of the algorithm

• Given 2 strings S1 and S2:
  – normalize S1 and S2
  – compute the group of *n*-grams of S1: \( G1 \)
  – compute the number of *n*-grams in \( G1 \) that are in S2: \( nG1\_in\_S2 \)
  – result is:

\[
\begin{align*}
nG1\_in\_S2 & \geq 0 \\
& \leq \frac{1}{|G1|}
\end{align*}
\]

• Virtues:
  – robustness to misspells
  – language independence
WordNet

- **WordNet**
  - lexical database for English
  - contains thousands of words grouped into *synsets*, which are then semantically related

- **WordNet::Similarity**
  - provides measures of similarity and relatedness
    - Resnik, Jiang-Conrath, Leacock-Chodorow, Hirst-St.Onge, Wu-Palmer, ...
  - similarity: based on information contained in a hierarchical model
    - ‘automobile’ is more similar to ‘boat’ than to ‘tree’, because they share ‘vehicle’ as ancestor
  - relatedness: based on relations like “has part” or “is made of”
    - ‘wheel’ is related to ‘car’ because it is one of its attributes
Leacock-Chodorow (LCH)

- In WordNet
  - 1 concept = n meanings (synsets)
- LCH calculates the length of the shortest path between two concepts, counting up the number of edges between their meanings in a WordNet hierarchy

<table>
<thead>
<tr>
<th>Word 1</th>
<th>Word 2</th>
<th>LCH score</th>
</tr>
</thead>
<tbody>
<tr>
<td>klaxon#1</td>
<td>horn#1</td>
<td>1.7918</td>
</tr>
<tr>
<td>klaxon#1</td>
<td>horn#2</td>
<td>1.0186</td>
</tr>
<tr>
<td>klaxon#1</td>
<td>horn#3</td>
<td>0.8109</td>
</tr>
<tr>
<td>klaxon#1</td>
<td>horn#4</td>
<td>1.0986</td>
</tr>
<tr>
<td>klaxon#1</td>
<td>horn#5</td>
<td>1.5041</td>
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</tbody>
</table>

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<tr>
<td>klaxon#1</td>
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<tr>
<td>klaxon#1</td>
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<td>klaxon#1</td>
<td>horn#8</td>
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<td>klaxon#1</td>
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<tr>
<td>klaxon#1</td>
<td>horn#10</td>
<td>2.1972</td>
</tr>
</tbody>
</table>

Mapping Process

- Target class → set of candidate classes
  - choose best matching class

- Matching score between target (TC) and candidate class (CC)

  1. Compute class name similarity score $ns$
  2. Compute attribute list similarity score $as$
     - map every attribute in TC with attributes in CC
  3. Return average of $ns$ and $as$

- Similarity score

  1. Compute N-Grams similarity score $ngs$
  2. If $ngs$ is satisfactory then return $ngs$
  3. Compute WordNet similarity score $wns$
  4. Return max($ngs$, $wns$)
Example

**Ontology A**
- Control
- Cutout
- Siren
- Photographic_Equipment

**Ontology B**
- Command
- Switch
- Alarm
- Camera

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>price</td>
<td>all</td>
</tr>
<tr>
<td>range</td>
<td>Control</td>
</tr>
<tr>
<td>cipher</td>
<td>Control</td>
</tr>
<tr>
<td>num_button</td>
<td>Cutout</td>
</tr>
<tr>
<td>decibel</td>
<td>Siren</td>
</tr>
<tr>
<td>wireless</td>
<td>Photographic_Equipment</td>
</tr>
<tr>
<td>sight_grade</td>
<td>Photographic_Equipment</td>
</tr>
<tr>
<td>lens_dimension</td>
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<tr>
<td>reach</td>
<td>Command</td>
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<tr>
<td>code</td>
<td>Command</td>
</tr>
<tr>
<td>number_button</td>
<td>Switch</td>
</tr>
<tr>
<td>db</td>
<td>Alarm</td>
</tr>
<tr>
<td>has_wireless</td>
<td>Camera</td>
</tr>
<tr>
<td>vision_angle</td>
<td>Camera</td>
</tr>
<tr>
<td>lens_size</td>
<td>Camera</td>
</tr>
</tbody>
</table>

*N-Grams*  
*WordNet*
Results

<table>
<thead>
<tr>
<th>Ontology A</th>
<th>Ontology B</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photographic_Equipment</td>
<td>Camera</td>
<td>0.81 (WordNet)</td>
</tr>
<tr>
<td>price</td>
<td>price</td>
<td>1.00 (N-Grams)</td>
</tr>
<tr>
<td>wireless</td>
<td>has_wildless</td>
<td>0.64 (N-Grams)</td>
</tr>
<tr>
<td>lens_dimension</td>
<td>lens_size</td>
<td>0.85 (WordNet)</td>
</tr>
<tr>
<td>sight_grade</td>
<td>vision_angle</td>
<td>0.73 (WordNet)</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Ontology A</th>
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<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Command</td>
<td>0.97</td>
</tr>
<tr>
<td>Cutout</td>
<td>Switch</td>
<td>0.82</td>
</tr>
<tr>
<td>Siren</td>
<td>Alarm</td>
<td>0.90</td>
</tr>
<tr>
<td>Photographic_Equipment</td>
<td>Camera</td>
<td>0.81</td>
</tr>
</tbody>
</table>
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Normative Environment
Norms in Multi-Agent Systems

- Imposed, compile-time, rigid
  - “rules of the game”, interaction conventions
  - Restriction on behavior, regimentation
  - Norm violation, reactive enforcement

- Normative support, default norms
  - Contract negotiation
  - Norm adoption
  - Norm negotiation

- Social norm emergence, patterns of behavior

- Emergent, run-time, loose
Norms

• Definition 1
  – Informal guideline about what is considered normal (what is correct or incorrect) social behavior in a particular group or social unit. Norms form the basis of collective expectations that members of a community have from each other, and play a key part in social control and social order by exerting a pressure on the individual to conform. In short, "The way we do things around here."

• Definition 2
  – Formal rule or standard laid down by legal, religious, or social authority against which appropriateness (what is right or wrong) of an individual's behavior is judged.

Source: http://www.businessdictionary.com/
Institutional Normative Environment

\[ \text{Normative Environment } NE = \langle \text{REA, BF, CR, NS, IR, N} \rangle \]
Context

- **Contract**: a normative context

\[
\text{Context } C = \langle PC, CA, CI, CN \rangle
\]

- **Context hierarchies**
  - Contractual agreement: business context for more specific contracts
  - Sub-context:

\[
C' \prec C \quad \text{or if } PC'' \prec C
\]
Hierarchical Normative Framework

- Normative background that assists contract establishment
- “Default rules” (contract law)
Institutional Rules and Norms

• Rules

\[ IR ::= \text{Antecedent} \rightarrow \text{Consequent} \]

\[ IRE^C \]
\[ \leq \geq \]

\[ IRE^C \rightarrow \]
\[ obl^C(...) \]

• Semantics of rules: substitution in FOL
  – substitution \( \Theta \) matches \textit{Antecedent} with \( NS \)
  – apply \( \Theta \) to \textit{Consequent} and add fully-ground atomic formulae to \( NS \)

• Norms

\[ N^C ::= \text{Situation}^{C'} \rightarrow \text{Prescription}^{C'} \]

\[ Info^C \]
\[ IRE^C \]
\[ \leq \geq \]
\[ obl^C(...) \]

• Norm \( N^C \) is
  – \textit{defined in context} \( C \)
  – \textit{applicable to} \( C \) or to a sub-context \( C' \)

• Two kinds of elements in \textit{Situation}^{C'}:
  – \textit{background} \( Sb \)
    • exist at context creation: \( Info^{C'} \)
  – \textit{contingent} \( Sc \)
    • added later to \( NS: IRE^{C'} \)
Norm Semantics

- **Norm activation**
  \[ N^C = S_b \land S_c \land ... \rightarrow P^C' \]
  applicable to \( C' = \langle PC', CA', CI', CN' \rangle \)

  subst \( \Theta \)

  \( \forall b \in S_b \ b \cdot \Theta \in CI' \)

  \( \forall c \in S_c \ c \cdot \Theta \in NS \)

- **Norm activation conflict**

<table>
<thead>
<tr>
<th>norm</th>
<th>substitution</th>
<th>activation</th>
<th>contingent facts</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N_1^{C_1} = S_{b_1} \land S_{c_1} \land ... \rightarrow P_1^{C_1'} )</td>
<td>( \Theta_1 )</td>
<td>( \text{Act}_1 )</td>
<td>( NS_1 = { c \cdot \Theta_1</td>
</tr>
<tr>
<td>( N_2^{C_2} = S_{b_2} \land S_{c_2} \land ... \rightarrow P_2^{C_2'} )</td>
<td>( \Theta_2 )</td>
<td>( \text{Act}_2 )</td>
<td>( NS_2 = { c \cdot \Theta_2</td>
</tr>
</tbody>
</table>

- \( \text{Act}_1 \otimes \text{Act}_2 \) if \( NS_1 = NS_2 \) and either \( C_1 \triangleleft C_2 \) or \( C_2 \triangleleft C_1 \)

- **Norm activation defeasance**
  - \( \text{Act}_1 \) defeats \( \text{Act}_2 \) if \( \text{Act}_1 \otimes \text{Act}_2 \) and \( C_1 \triangleleft C_2 \)
Norm Contextual Target

• Norms may pre-exist to the contexts to which they apply
• Norms may apply to more than one context

• Relax norm applicability
  – from a sub-context to a range of sub-contexts
  – typify contexts: $C' = Id:Type$

$N^C = S^{C'} \rightarrow P^{C'}$

• patterns of $Info^{C'}$ and $IRE^{C'}$ within $S^{C'}$: $Info^{id:T}$, $IRE^{id:T}$
  – unbound var $id$: match $Info$’s and $IRE$’s of any sub-context of type $T$
• substitution $\Theta$ binds $id$ to a specific sub-context
Example

- Supply-agreement: **SA** context type
  - norm at top institutional context

\[
\begin{align*}
N_{\text{Inst}}^1 & = \text{Fact}^a_{\text{Inst}:\text{SA}}(\text{Order}(r, \text{From}: a1, \text{To}: a2, \text{Product}: p, \text{Quantity}: q)) \wedge \\
& \wedge \text{SupplyInfo}^a_{\text{Inst}:\text{SA}}(\text{Agent}: a2, \text{Product}: p, \text{UnitPrice}: \text{up}) \\
\rightarrow & \text{Obj}^a_{\text{Inst}:\text{SA}}(\text{Delivery}(r, \text{From}: a2, \text{To}: a1, \text{Product}: p, \text{Quantity}: q) < t + 2) \wedge \\
& \text{Obj}^a_{\text{Inst}:\text{SA}}(\text{Payment}(r, \text{From}: a1, \text{To}: a2, \text{Amount}: q \times \text{up}) < t + 2)
\end{align*}
\]

- sub-context: **SA3:SA** \(\triangleleft\) **Inst**

\[
\begin{align*}
N_{\text{SA3:SA}}^1 & = \text{Fact}^a_{\text{SA3:SA}}(\text{Order}(r, \text{From}: \text{Jim}, \text{To}: a1, \text{Product}: p, \text{Quantity}: q)) \wedge \\
& \wedge \text{SupplyInfo}^a_{\text{SA3:SA}}(\text{Agent}: \text{Jim}, \text{Product}: p, \text{UnitPrice}: \text{up}) \wedge q > 99 \\
\rightarrow & \text{Obj}^a_{\text{SA3:SA}}(\text{Delivery}(r, \text{From}: \text{Jim}, \text{To}: a1, \text{Product}: p, \text{Quantity}: q) < t + 2) \wedge \\
& \text{Obj}^a_{\text{SA3:SA}}(\text{Payment}(r, \text{From}: a1, \text{To}: \text{Jim}, \text{Amount}: q \times \text{up}) < t + 2)
\end{align*}
\]

\[
\begin{align*}
N_{\text{SA3:SA}}^2 & = \text{Fact}^a_{\text{SA3:SA}}(\text{Order}(r, \text{From}: \text{Sam}, \text{To}: a2, \text{Product}: p, \text{Quantity}: q)) \wedge \\
& \wedge \text{SupplyInfo}^a_{\text{SA3:SA}}(\text{Agent}: a2, \text{Product}: p, \text{UnitPrice}: \text{up}) \\
\rightarrow & \text{Obj}^a_{\text{SA3:SA}}(\text{Delivery}(r, \text{From}: a2, \text{To}: \text{Sam}, \text{Product}: p, \text{Quantity}: q) < t + 2)
\end{align*}
\]

\[
\begin{align*}
N_{\text{SA3:SA}}^3 & = \text{Fact}^a_{\text{SA3:SA}}(\text{Order}(r, \text{From}: \text{Sam}, \text{To}: a2, \text{Product}: p, \text{Quantity}: q)) \wedge \\
& \wedge \text{SupplyInfo}^a_{\text{SA3:SA}}(\text{Agent}: a2, \text{Product}: p, \text{UnitPrice}: \text{up}) \\
\rightarrow & \text{Obj}^a_{\text{SA3:SA}}(\text{Payment}(r, \text{From}: \text{Sam}, \text{To}: a2, \text{Amount}: q \times \text{up}) < t + 2)
\end{align*}
\]
Example (2)

\[ N_{\text{Inst}}^1 \]
\[ \text{Ifact}^{\text{SA3:SA}} (\text{Order}(\text{Ref} : r, \text{From} : a_1, \text{To} : a_2, \text{Product} : p, \text{Quantity} : q)) \land \]
\[ \text{SupplyInfo}^{\text{SA3:SA}} (\text{Agent} : a_2, \text{Product} : p, \text{UnitPrice} : \text{up}) \]
\[ \rightarrow \]
\[ \text{Obli}^{\text{SA3:SA}} (\text{Delivery}(\text{Ref} : r, \text{From} : a_2, \text{To} : a_1, \text{Product} : p, \text{Quantity} : q) < t + 2) \land \]
\[ \text{Obli}^{\text{SA3:SA}} (\text{Payment}(\text{Ref} : r, \text{From} : a_1, \text{To} : a_2, \text{Amount} : q \times \text{up}) < t + 2) \]

\[ N_{\text{Inst}}^2 \]
\[ \text{Ifact}^{\text{SA3:SA}} (\text{Order}(\text{Ref} : r, \text{From} : \text{Sam}, \text{To} : a_2, \text{Product} : p, \text{Quantity} : q)) \land \]
\[ \text{SupplyInfo}^{\text{SA3:SA}} (\text{Agent} : a_2, \text{Product} : p, \text{UnitPrice} : \text{...}) \]
\[ \rightarrow \]
\[ \text{Obli}^{\text{SA3:SA}} (\text{Delivery}(\text{Ref} : r, \text{From} : a_2, \text{To} : \text{Sam}, \text{Product} : p, \text{Quantity} : q) < t + 2) \]

\[ N_{\text{Inst}}^3 \]
\[ \text{Ifact}^{\text{SA3:SA}} (\text{Order}(\text{Ref} : r, \text{From} : \text{Jim}, \text{To} : \text{Tom}, \text{Product} : \text{P3}, \text{Quantity} : \text{5})) \]
\[ \rightarrow \]
\[ \text{Obli}^{\text{SA3:SA}} (\text{Delivery}(\text{Ref} : r, \text{From} : \text{Tom}, \text{To} : \text{Sam}, \text{Product} : \text{P3}, \text{Quantity} : \text{5}) < 3) \]
\[ \text{Ful}^{\text{SA3:SA}} (\text{Delivery}(\text{Ref} : r, \text{From} : \text{Tom}, \text{To} : \text{Sam}, \text{Product} : \text{P3}, \text{Quantity} : \text{5}) < 3) \]

\[ \text{NS} \]
\[ \text{Ifact}^{\text{SA3:SA}} (\text{Order}(\text{Ref} : 1, \text{From} : \text{Jim}, \text{To} : \text{Tom}, \text{Product} : \text{P3}, \text{Quantity} : \text{5})) \]
\[ \text{Ifact}^{\text{SA3:SA}} (\text{Order}(\text{Ref} : 3, \text{From} : \text{Tom}, \text{To} : \text{Jim}, \text{Product} : \text{P1}, \text{Quantity} : \text{100})) \]
\[ \text{Ifact}^{\text{SA3:SA}} (\text{Order}(\text{Ref} : 4, \text{From} : \text{Sam}, \text{To} : \text{Tom}, \text{Product} : \text{P3}, \text{Quantity} : \text{5})) \]
\[ \text{Ifact}^{\text{SA3:SA}} (\text{Order}(\text{Ref} : 4, \text{From} : \text{Sam}, \text{To} : \text{Tom}, \text{Product} : \text{P3}, \text{Quantity} : \text{5})) \]
\[ \text{Obli}_1^{\text{SA3:SA}} (\text{Delivery}(\text{Ref} : 4, \text{From} : \text{Tom}, \text{To} : \text{Sam}, \text{Product} : \text{P3}, \text{Quantity} : \text{5}) < 3) \]
\[ \text{Ifact}^{\text{SA3:SA}} (\text{Order}(\text{Ref} : 4, \text{From} : \text{Sam}, \text{To} : \text{Tom}, \text{Product} : \text{P3}, \text{Quantity} : \text{5})) \]
\[ \text{Obli}_4^{\text{SA3:SA}} (\text{Delivery}(\text{Ref} : 4, \text{From} : \text{Tom}, \text{To} : \text{Sam}, \text{Product} : \text{P3}, \text{Quantity} : \text{5}) < 3) \]

\[ \text{Conflicts} \]
none, \( N_{\text{Inst}}^1 \) applies
\( N_{\text{Inst}}^1 \) defeats \( N_{\text{Inst}}^3 \)

none, \( N_{\text{Inst}}^3 \) applies
Scenarios

• **Contract of sale**
  – Typical
    • delivery → payment
  – “Atypical”: exploit norm defeasibility
    • delivery → trial period, not returned → payment

• **Standing agreements**
  – Long-term contract: normative context for more short-termed contracts
  – Enterprise cluster → Cooperation agreement → Contract of sale

• **Workflow multi-party contracts**
  – Business process specifying actions to be performed between contract participants
Rule-based Automated Monitoring

- Inference Engine
- Working Memory
  - Institutional Facts
  - Time
  - Obligations
  - Liveline Violations
  - Deadline Violations
  - Fulfilments
  - Violations
  - Denounces

- Knowledge Base
  - Monitoring Rules
  - Contracts (Norms)
Contractual Obligations

Directed Obligation with Time Window

Agent $b$ is obliged towards agent $c$ to bring about fact $f$ between liveline $l$ and deadline $d$

- $f$ should occur within the time window $[l; d]$
- having $f$ before reaching $l$ causes a liveline violation
- reaching $d$ without having $f$ causes a deadline violation
- counterparty $c$ is authorized to react if a liveline or deadline violation occurs

\[ Obl_{b,c}(l \prec f \prec d) \]

- \( c \) authorized to react if $f$
- \( c \) authorized to react if $\neg f$

\((Obl_{b,c}(l \prec f \prec d) \) may still be fulfilled\)
Contractual Obligations (2)

- **inactive**: not prescribed yet
- **active**: $Obl_{b,c}(l < f < d)$
- **pending** – may be fulfilled
- **fulfilled**: $Fulf(obl)$
- **liveline violation**: $LViol(obl)$
- **deadline violation**: $DViol(obl)$
- **violated**: $Viol(obl)$
Monitoring Rules

Liveline violation

\[ Obl_{b,c}(l < f < d) \land Ifact(f) \land \neg Time(l) \rightarrow LViol(Obl_{b,c}(l < f < d)) \]

Liveline violation without denounce \( \rightarrow \) Fulfillment

\[ LViol(Obl_{b,c}(l < f < d)) \land Time(l) \land \neg Den_{c,b}(Obl_{b,c}(l < f < d)) \]
\[ \rightarrow Fulf(Obl_{b,c}(l < f < d)) \]

Liveline violation with denounce \( \rightarrow \) Violation

\[ LViol(Obl_{b,c}(l < f < d)) \land Den_{c,b}(Obl_{b,c}(l < f < d)) \land \neg Time(l) \]
\[ \rightarrow Viof(Obl_{b,c}(l < f < d)) \]

Fulfillment within due time

\[ Obl_{b,c}(l < f < d) \land Time(l) \land \neg LViol(Obl_{b,c}(l < f < d)) \land Ifact(f) \land \neg Time(d) \]
\[ \rightarrow Fulf(Obl_{b,c}(l < f < d)) \]

Deadline violation

\[ Obl_{b,c}(l < f < d) \land Time(d) \land \neg Ifact(f) \rightarrow DViol(Obl_{b,c}(l < f < d)) \]

Deadline violation without denounce \( \rightarrow \) Fulfillment

\[ DViol(Obl_{b,c}(l < f < d)) \land Ifact(f) \land \neg Den_{c,b}(Obl_{b,c}(l < f < d)) \]
\[ \rightarrow Fulf(Obl_{b,c}(l < f < d)) \]

Deadline violation with denounce \( \rightarrow \) violation

\[ DViol(Obl_{b,c}(l < f < d)) \land Den_{c,b}(Obl_{b,c}(l < f < d)) \land \neg Ifact(f) \]
\[ \rightarrow Viof(Obl_{b,c}(l < f < d)) \]
Contract Model

• Requirements
  – include data for context definition and context-dependent information
    • valid contracts for institutionally defined norms
  – add contract-specific norms
    • override default institutional norms
  – expand predicted contract scenarios
    • new institutional facts
    • new context types
Contract Header

context definition

context-dependent information
Contract-Specific Norms

- Norm definition
  - *un-typed* contexts
    - define the whole normative relationship
  - *typed* context
    - override default institutional norms
Contract-Specific Rules

• Iterating through Institutional Facts
  – not restricting applicability to predicted contracting situations
  – context-dependent
    • contract fulfillment may be adjusted by matters of trust or business specificities
    • ontology expansion
      – define new institutional facts through rules
      – define norms employing these new institutional facts
Contract Handling in the EI

- Contract establishment
  - after negotiation and before execution
Electronic Institution Platform for B2B Contracting

Computational Trust and Reputation
Computational Trust Systems

• They estimate the trustworthiness of agents in order to assist some specific trusting decision

• A computational handling of trust is critical to enable automating business processes between companies

• There are three main research challenges:
  1. How to build trust
  2. Which information sources must be considered
  3. How to formalize the process of trust building into a model
How to Build Trust

• Different perspectives (theories from Psychology, Philosophy, Social Science, Economics):
  – Dispositional vs. socio-cognitive
  – Rationality vs. predictability
  – Trust as knowledge vs. trust as act

• Dynamics of Trust
  – Reciprocity
  – Asymmetry
  – Forgiveness
  – “Maturity”
  – Situational-awareness
Which Information Sources to Use

- Direct experience
- Contractual evidences
- Shared images / opinions
- Reputation (as a social evaluation)
- Certificates / recommendations
- Roles in an institution
- Rules defined in the community
- Group trust
- Social networks (twitter, facebook, linkedin) / Internet
How to Model Trust

- **FIRE** (Huynh et al., 2006) models direct trust as a weighted means by recency:

\[
T(N) = \frac{\sum_{i=0}^{N-1} w_i \cdot v_i}{\sum_{i=0}^{N-1} w_i}, \quad w_i = e^{-\frac{\Delta t_i}{\lambda}}, \quad \lambda = -\frac{d}{\ln(0.5)}
\]
How to Model Trust

- The **Beta Reputation System** (Josang et al., 2002) and **TRAVOS** (Patel et al., 2007) model direct trust and reputation as the expectation of a beta PDF:

\[
\tau_{a_1,a_2} = E[B_{a_1,a_2} \mid O_{a_1,a_2}^{1:t}] = \frac{\alpha}{\alpha + \beta}
\]

How to Model Trust

• The **socio-cognitive model of trust** (Castelfranchi et al., 2010) models trust as Fuzzy Cognitive Maps:

http://t3.istc.cnr.it/trustwiki/index.php/Trust_as_a_fuzzy_network
How to Model Trust

• The model by Rehak et al. (2008) represents the situation as a point in a multi-dimensional context space

\[
T(N) = \frac{\sum_{i=0}^{N-1} W_i \cdot v_i}{\sum_{i=0}^{N-1} W_i}, \quad w_i = e^{-d(c1,c2)}
\]
Our Computational Trust Model

**Motivation:**

1. The model must perform well when the number of evidences on the target agent is small
2. The model should be situational-aware
3. The model should incorporate known properties of the dynamics of trust

– Additionally, contractual evidences should be used whenever available
The Original Intuition

• The asymmetry principle of human psychology (Slovic, 1993)

• The hysteresis of trust and betrayal, by Straker (2008)

\[
x(\alpha) = a \cdot \cos^m \alpha + b_x \cdot \sin^n \alpha \\
y(\alpha) = b_y \cdot \sin \alpha
\]

Lapshin (1995)
The Sinalpha Aggregation Engine

- Desired Characteristics:
  - Asymmetry
  - Maturity
  - Distinguishable past
  - Embedded personality of trusting agents

\[ y(\alpha) = \delta \cdot \sin \alpha + \delta \]

\[ \alpha_{\text{min}} = \frac{3\pi}{2}, \quad \alpha_{\text{max}} = \frac{5\pi}{2} \]

\[ \alpha = \alpha + \lambda \omega \]
The Contextual Fitness Tuner

Sinalpha considers that this is a good supplier, but it is not able to detect his failure tendencies (if any)

Contextual Fitness is a machine learning based module that extracts tendencies of behavior in a dynamic and incremental way

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The Contextual Fitness Tuner

1. Generates a classification tree using the information gain metric:

   \[ \text{Gain}(S, A) \equiv \text{Entropy}(S) - \sum_{v \in \text{Values}(A)} \frac{|S_v|}{|S|} \text{Entropy}(S_v) \]

2. Derives the tendencies of behavior from the rules

3. If any tendency of failure matches current situation, the global trustworthiness value of the supplier is zero

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Tendency of failure = (*, high, low)
Evaluation of the Model

- Sinalpha has similar performance than the model of Jonker and Treur (2008) and outperforms models based on weighted means
- Contextual Fitness outperforms Rehak’s model, as it is more effective in learning the behavior of partners when the available evidences are scarce
- We are currently evaluating the benefits of personalizing Sinalpha
Future Work

- Using outcomes with multiple values (ongoing)
- Using heterogeneous evidences
- Automating the generation of contractual evidences from normative events (ongoing)
- Developing models of behavior for agents to better evaluate and compare the trust model
Electronic Institution Platform for B2B Contracting

Implementation
Class Diagram
Interaction Protocols

Negotiation Process
Interaction Protocols (2)

Contracting Process
Interaction Protocols (3)

Monitoring Process

Diagram showing interactions between EnterpriseAgent, NegotiationMediator, Reputation, Notary, NormativeEnvironment, and ExternalAgent with messages such as `subscribe(contract)`, `inform(contract-event)`, `request(transaction)`, `inform(done)`, and `inform(transaction)`. The diagram uses FIPA-Subscribe and FIPA-Request protocols.