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
Electronic Institution Platform for B2B Contracting

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”
VE Lifecycle

 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

- Call
  - Issued by a Market Agent
  - Specifies the Good, as a set of components
  - Specifies each Component as a set of attributes with admissible value ranges (without specifying an utility function)

- Making an initial proposal
  - Issued by those Enterprise Agents that are competent to satisfy the announced component(s)
  - The proposal includes those values that are preferable to the Enterprise Agent (while satisfying the admissible ranges)
Q-Negotiation

• Proposal evaluation
  – Quantifies the deviation of the values in the proposal as compared to the optimal values
    \[
    Ev = \frac{1}{Deviation}, \quad \text{Deviation} = \frac{1}{\sum_{i=1}^{k}} \sum_{i}^{k} \left( k - i + 1 \right)^{a} \text{dif}(\text{Pref}_{V}, V_{i})
    \]

• Making a qualitative comment
  – A qualitative value (sufficient, bad, mediocre) is attributed to each of the attributes in the proposal
  – Describes the distance between the values of the current proposal and those of the best proposal received so far

  to say that there is a better proposal in the market is more convincing than to say that the current proposal is not optimal

Q-Negotiation

• Remaking a proposal
  – Uses an algorithm based on Q-learning
    \[
    Q(e,a) = Q(e,a) + \alpha \left( r + \gamma \max_{b} Q(e',b) - Q(e,a) \right)
    \]
  – Actions included in the exploration space are deduced according to the received comment
    • state: \( s = <c_{1}, c_{2}, ..., c_{k}> \), \( c_{i} \): qualitative comment relative to attribute \( i \)
    • action: \( a = <a_{1}, a_{2}, ..., a_{k}> \), \( a_{i} \in \{\text{increment, decrement, maintain}\} \)
  – Reward value is calculated according to the qualitative comment received (immediate reward)
    \[
    r = \begin{cases} 
    k, & \text{if winning} \\
    k/2 - \sum \text{penalty}, & \text{if not winning} \quad (0 \leq \text{penalty} \leq 1)
    \end{cases}
    \]
Electronic Institution Platform for B2B Contracting

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)

Protégé (http://protege.stanford.edu/)
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

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 \( S_1 \) and \( S_2 \):
  – normalize \( S_1 \) and \( S_2 \)
  – compute the group of \( n \)-grams of \( S_1 \): \( G_1 \)
  – compute the number of \( n \)-grams in \( G_1 \) that are in \( S_2 \): \( nG_1 \_in \_S2 \)
  – result is:

\[
\frac{nG_1 \_in \_S2}{|G_1|} \leq 1
\]

• **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
Mapping Process

- Target class $\rightarrow$ 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

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

N-Grams

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>db</td>
<td>Alarm</td>
</tr>
<tr>
<td>has_wireless</td>
<td>Camera</td>
</tr>
</tbody>
</table>

WordNet

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>lens_size</td>
<td>Camera</td>
</tr>
</tbody>
</table>
### 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_wireless</td>
<td>0.84 (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>
<thead>
<tr>
<th>Ontology A</th>
<th>Ontology B</th>
<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>

### Electronic Institution Platform for B2B Contracting

Normative Environment
Norms in Multi-Agent Systems

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

Normative Environment \( NE = \langle REA, BF, CR, NS, IR, N \rangle \)

Hierarchical Normative Framework

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

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

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

- Semantics of rules: substitution in FOL
  - substitution \( \theta \) matches Antecedent with \( NS \)
  - apply \( \theta \) to Consequent and add fully-ground atomic formulae to \( NS \)

- Norm \( N^C \) is
  - defined in context \( C \)
  - applicable to \( C \) or to a sub-context \( C' \)

- Two kinds of elements in \( \text{Situation}^C \):
  - background (\( S_b \))
    - exist at context creation: Info\( ^C \)
  - contingent (\( S_c \))
    - added later to \( NS; \text{IRE}^C \)

---

Norm Semantics

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

- Norm activation conflict
  \[ \forall_{b \in S_b} b \in C' \land \forall_{c \in S_c} c \in NS \]

- Norm activation defeasance
  - \( \theta_1 \) defeats \( \theta_2 \) if \( \theta_1 \) and either \( C_1 \not\subset C_2 \) or \( C_2 \not\subset C_1 \)

- Norm activation defeasance
  - \( \theta_1 \) defeats \( \theta_2 \) if \( \theta_1 \) and \( C_1 \not\subset C_2 \)
Example

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

- sub-context: $SA3:SA < Inst$

Example (2)

<table>
<thead>
<tr>
<th>NS</th>
<th>Conflict</th>
</tr>
</thead>
<tbody>
<tr>
<td>$NS^{SA3:SA}$</td>
<td>none, $N^{SA2:SA}$ applies</td>
</tr>
<tr>
<td>$NS^{SA3:SA}$</td>
<td>$N^{SA2:SA}$ defeats $N^{SA3:SA}$</td>
</tr>
<tr>
<td>$NS^{SA3:SA}$</td>
<td>$N^{SA2:SA}$ defeats $N^{SA3:SA}$</td>
</tr>
<tr>
<td>$NS^{SA3:SA}$</td>
<td>none, $N^{SA3:SA}$ applies</td>
</tr>
</tbody>
</table>
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
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

![Directed Obligation with Time Window Diagram]

Contractual Obligations (2)

- **inactive**: not prescribed yet
- **active**: $\text{Obh}_{b,c}(l \prec f \prec d)$
- **pending** – may be fulfilled
- **fulfilled**: $\text{Ful}(\text{obl})$
- **liveline violation**: $LVio(\text{obl})$
- **deadline violation**: $DVio(\text{obl})$
- **violated**: $\text{Viol}(\text{obl})$
Monitoring Rules

Liveline violation
\[ \text{Liviol}(l < f < d) \land \text{Ifact}(f) \land \neg \text{Time}(l) \rightarrow \text{Liviol}(l < f < d) \]

Liveline violation without denounce \rightarrow Fulfillment
\[ \text{Liviol}(l < f < d) \land \text{Time}(l) \land \neg \text{Denowl}(l < f < d) \]
\[ \rightarrow \text{Fulf}(l < f < d) \]

Liveline violation with denounce \rightarrow Violation
\[ \text{Liviol}(l < f < d) \land \text{Denowl}(l < f < d) \land \neg \text{Time}(l) \]
\[ \rightarrow \text{Viol}(l < f < d) \]

Fulfillment within due time
\[ \text{Obgl}(l < f < d) \land \text{Time}(l) \land \neg \text{Liviol}(l < f < d) \land \text{Ifact}(f) \land \neg \text{Time}(d) \rightarrow \text{Fulf}(l < f < d) \]

Deadline violation
\[ \text{Obgl}(l < f < d) \land \text{Time}(l) \land \neg \text{Iact}(f) \rightarrow \text{Dviol}(l < f < d) \]

Deadline violation without denounce \rightarrow Fulfillment
\[ \text{Dviol}(l < f < d) \land \text{Iact}(f) \land \neg \text{Denowl}(l < f < d) \]
\[ \rightarrow \text{Fulf}(l < f < d) \]

Deadline violation with denounce \rightarrow Violation
\[ \text{Dviol}(l < f < d) \land \text{Denowl}(l < f < d) \land \neg \text{Iact}(f) \]
\[ \rightarrow \text{Viol}(l < f < d) \]

Contract Header

[Diagram of Contract Header]

context definition

[Diagram of Contract Header]

context-dependent information
Contract-Specific Norms

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

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:

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

• 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:

\[
\tau_{a1,a2} = E[B_{a1,a2} \mid O_{a1,a2}^{1:t}] = \frac{\alpha}{\alpha + \beta}
\]
How to Model Trust

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

  [Diagram of Fuzzy Cognitive Maps]

  [Link: http://t3.istc.cnr.it/trustwiki/index.php/Trust_as_a_fuzzy_network]

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

  \[ T(N) = \sum_{i=1}^{N-1} W_i \cdot V_i, \quad W_i = e^{-d(x_1,x_2)} \]
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 Sinalpha Aggregation Engine

**Desired Characteristics:**

- Asymmetry
- Maturity
- Distinguishable past
- Embedded personality of trusting agents

\[ y(\alpha) = \delta \cdot \sin \alpha + 3 \]
\[ \alpha_{\text{min}} = \frac{3\pi}{2}, \quad \alpha_{\text{max}} = \frac{5\pi}{2} \]
\[ \alpha = \frac{\alpha - \frac{\pi}{2}}{\pi} \]
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

<table>
<thead>
<tr>
<th>fabric</th>
<th>quantity</th>
<th>del. time</th>
<th>outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>cotton</td>
<td>medium</td>
<td>big</td>
<td>true</td>
</tr>
<tr>
<td>cotton</td>
<td>high</td>
<td>medium</td>
<td>true</td>
</tr>
<tr>
<td>cotton</td>
<td>medium</td>
<td>big</td>
<td>true</td>
</tr>
<tr>
<td>voile</td>
<td>medium</td>
<td>medium</td>
<td>true</td>
</tr>
<tr>
<td>voile</td>
<td>high</td>
<td>low</td>
<td>false</td>
</tr>
<tr>
<td>cotton</td>
<td>high</td>
<td>medium</td>
<td>true</td>
</tr>
<tr>
<td>voile</td>
<td>medium</td>
<td>big</td>
<td>true</td>
</tr>
<tr>
<td>voile</td>
<td>high</td>
<td>big</td>
<td>true</td>
</tr>
<tr>
<td>cotton</td>
<td>low</td>
<td>big</td>
<td>true</td>
</tr>
<tr>
<td>voile</td>
<td>medium</td>
<td>medium</td>
<td>true</td>
</tr>
<tr>
<td>cotton</td>
<td>high</td>
<td>medium</td>
<td>true</td>
</tr>
<tr>
<td>voile</td>
<td>medium</td>
<td>low</td>
<td>true</td>
</tr>
<tr>
<td>voile</td>
<td>medium</td>
<td>big</td>
<td>true</td>
</tr>
<tr>
<td>voile</td>
<td>medium</td>
<td>low</td>
<td>true</td>
</tr>
</tbody>
</table>

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

   \[
   \text{Gain}(S,A) = \text{Entropy}(S) - \sum_{S_i \in \text{values(A)}} \frac{|S_i|}{|S|} \text{Entropy}(S_i)
   \]

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

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.

Problems

- Traditional approaches fail to correctly model trust:
  - Trust is a socio-cognitive concept.
  - Trustworthiness is not single dimensional.
  - Trust is more than trustworthiness.
  - Approaches are evaluated using extremely simple agent behaviour models.
The SOLUM Framework

Electronic Institution Platform for B2B Contracting

Implementation
Class Diagram

Interaction Protocols

Negotiation Process
Interaction Protocols (2)

Contracting Process

Interaction Protocols (3)

Monitoring Process