Monitoring and Explanation of Contract Execution:
A Case Study in the Aerospace Domain

Felipe Meneguzzi  Sanjay Modgil
Nir Oren  Simon Miles  King’s College London
Michael Luck

Nora Faci  University of Lyon

Camden Holt  Gary Vickers  Lost Wax
Outline

• Motivation and Context
• Aerospace Aftermarket
• Monitoring Contract Fulfilment
• Explanations of Violations
• Simulation Scenarios
• Conclusions and Related Work
INTRODUCTION
Electronic Contracts in MAS

- Systems of self-interested agents:
  - Inherently unreliable
  - Require societal control

- Norms used to regulate agent behaviour:
  - Encourage compliance with societal goals
  - Expressed using deontic concepts

- Norms incorporated into an agreed formal document → *Contract*
Electronic Contracts in Use

• Many domains match the pattern of self-interested but co-operating agents
• For example, businesses use each others’ services without assuming that everything in their own interest is in the interest of others
• People draw up contracts to formalise business relationships or transactions
• Electronic contracts allow automation of the processes surrounding contracts
The CONTRACT Project

• Aiming at an electronic contracting framework:
  – Facilitates design, verification, enactment, and management of contracts
  – Includes critical aspects of a contract life cycle

www.ist-contract.org
Use Cases

• The project draws requirements and inspiration from a set of use cases provided by companies
  – Insurance brokering
  – Testing services
  – Software provision
  – Aerospace aftermarket
Aerospace Aftermarket

- Aircraft operators purchase engines from engine manufacturers
- The engines need to be maintained over their lifetimes: aftercare
- This service is provided by the manufacturer but delegated down to particular sites where the planes can land and engines be serviced
Aftercare Contracts

• Consider contracts between engine manufacturers and service sites
• Contract obliges service site to service each engine within a given period
• Servicing requires ordering, fitting new engine parts
• There can be contractual restrictions on which part suppliers are acceptable
MONITORING CONTRACT FULFILMENT
### Representing Clauses

- A contractual clause is expressed by five elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Obligation or permission</td>
</tr>
<tr>
<td>Activation Condition</td>
<td>Conditions under which this clause takes force</td>
</tr>
<tr>
<td>Normative Condition</td>
<td>Conditions under which the obligation is being met or permission is taken advantage of</td>
</tr>
<tr>
<td>Expiration Condition</td>
<td>Conditions under which this clause ceases to take force</td>
</tr>
<tr>
<td>Target</td>
<td>The agent obliged or permitted by this clause</td>
</tr>
</tbody>
</table>
Case Study Clauses

• The clause below obliges the service site to service the engine in 7 days

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Obligation</td>
</tr>
<tr>
<td>Activation Condition</td>
<td>Engine E requires repair at time T</td>
</tr>
<tr>
<td>Normative Condition</td>
<td>Engine E is repaired or T + 7 days has not yet been reached</td>
</tr>
<tr>
<td>Expiration Condition</td>
<td>Engine E is repaired or T + 7 days has passed</td>
</tr>
<tr>
<td>Target</td>
<td>Service site</td>
</tr>
</tbody>
</table>

• Additionally, we have clauses to permit 2 part suppliers to be used and prohibit use of another
Monitoring

• An important factor for aftercare contracts is ensuring that the contract is adhered to, and violations are handled appropriately

• A key part of that is monitoring for compliance with contract clauses

A Framework for Monitoring Agent-Based Normative Systems, Modgil et al., AAMAS 2009
Domain Observations

- Agents interact through message exchanges
- These can be observed by the communicating agents themselves or intermediaries
Monitoring Status Representation

- Each clause monitored is represented as a graph
- As activating, normative or expiration conditions are observed, the graph is traversed to a new state
EXPLANATIONS OF VIOLATIONS
Explaining Contract Violations

• The observations which cause a monitor to transition from one state to another can be used as an explanation of a violation.
• However, this just provides the immediate context of a violation.
• For example, if an engine was not serviced within the time period, the observations would tell you which engine and when it required service.
Improving Explanations

• By its nature, monitoring involves data relevant to contract clauses to be acquired.
• We can improve explanations by making explicit where one clause is linked to another.
• For example, an engine part is ordered from a supplier because an engine requires servicing.
• We can also improve by adding and linking virtual clauses not in the contract but similarly monitored for explanation purposes.
SIMULATION SCENARIOS
Scenario 1

- We tested three scenarios
- In the first, repair is successfully completed on time

**Timeline:**
- **Engine Manufacturer**
  - Engine requires repair at time \( t \)
- **Site Service**
  - Engine repaired at time \( t + 6 \) days
- **Part Supplier 1**
  - Order part
- **Part Supplier 2**
  - Deliver part
- **Part Supplier 3**
Scenario 2

- In Scenario 2, the part supplier 1 cannot deliver parts on time, part supplier 2 delivers but late, delaying the repair.
Explanation from Monitoring

Obligation to repair engine within 7 days
(we exclude expiration states for brevity)
Explanation from Monitoring

Monitoring of permission to use Part Supplier 1

Also caused transition in prior clause

Not yet activated → Activated
- Repair request received

Activated → Not taken advantage
- Ask Part Supplier 1 to deliver part

Not taken advantage
- Part Supplier 1 not yet asked to deliver part

Taken advantage
Explanation from Monitoring

Virtual clause to monitor Supplier 1’s response

- Ask Part Supplier 1 to deliver part
  - Not yet activated
  - Activated
  - Part Supplier 1 not yet responded
  - Not taken advantage
  - Taken advantage
    - Part Supplier 1 responds: Unable to deliver part on time

Also caused transition in prior clause
Explanation from Monitoring

Monitoring of permission to use Part Supplier 2

Also caused transition in prior clause

- Repair request received
  - Not yet activated
  - Activated
    - Taken advantage
      - Ask Part Supplier 2 to deliver part
    - Not taken advantage
      - Part Supplier 2 not yet asked to deliver part
Explanation from Monitoring

Virtual clause to monitor Supplier 2’s response

- Not yet activated
- Activated
- Taken advantage
  - Part Supplier 2 responds: Deliver part
  - Part Supplier 2 not yet responded

Also caused transition in prior clause
Scenario 3

• In Scenario 3, part suppliers 1 and 2 cannot deliver parts, part supplier 3 is used even though prohibited by the contract.
[partManufacturerTwo] Notifying serviceSite of delivery
[serviceSite] Got delivery of engine1 from partManufacturerTwo
[ExternalAction] Notifying monitor of: send from 'partManufacturerTwo' to 'serviceSite' message 'delivered(partManufacturerTwo,engine1)'
[ExternalAction] Notifying monitor of: receive from 'serviceSite' to 'partManufacturerTwo' message 'delivered(partManufacturerTwo,engine1)'
[serviceSite] Fitting parts for engine1
[serviceSite] Parts fitted
[engineManufacturer] serviceSite repaired engine1
[ExternalAction] Notifying monitor of: send from 'serviceSite' to 'engineManufacturer' message 'engineRepaired(engine1)'
[ExternalAction] Notifying monitor of: receive from 'engineManufacturer' to 'serviceSite' message 'engineRepaired(engine1)'
DEADLINE IS EXPIRED !!!!
CONCLUSIONS AND RELATED WORK
Conclusions and Future Work

• Monitoring of electronic contracts adds value by allowing the diagnosis of contract violations.
• Our work allows explanations to be generated for violations, enabling such diagnosis.
• Future work:
  – Refine the detection and explanation algorithms.
  – Methodology to develop virtual clauses for improved explanation.