Exceptions and Accountability for Robust Applications of JaCaMo

EUMAS 2024 – Agent Toolkits Track

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August 28, 2024 - The 21st European Conference on Multi-Agent Systems August 26-28th, 2024, Dublin, Ireland

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Motivation

- Robustness is a crucial requirement of modern, distributed software systems [Jain et al., 1999, Kalia and Singh, 2015, Christie et al., 2021, Christie et al., 2022]
- Multi-Agent Systems are an effective approach to realize distributed systems by means of heterogeneous and autonomous agents
- Multi-agent *organizations* (MAOs), in particular, provide useful abstractions for modularizing code spread over many components, and orchestrate their execution by way of norms
  - JaCaMo [Boissier et al., 2020] is one of the best-known platforms for implementing multi-agent organizations

Motivation

- Unfortunately, JaCaMo focuses on providing the means for capturing the normal, correct behavior of the system only
- It lacks of structural mechanisms allowing agents to exchange and propagate information (*feedback*) when they face perturbations, thereby supporting robustness, a crucial feature to build robust distributed systems [Alderson and Doyle, 2010]
- Agents are peers (nor related by relationships like caller-callee, parent-child): the realization of robustness should occur through the definition of appropriate distributions of responsibilities among agents

JaCaMo+Exception+Accountability: our proposal

- We present two extensions to the JaCaMo platform:
  - **JaCaMo+Exception**:
    Exception handling is suitable for treating exception anticipated at design time by activating handlers, that are also specified at design time
  - **JaCaMo+Accountability**:
    Accountability is suitable for defining structured "channels" that agents can use at runtime to gain situational awareness about the situation of interest and then take actions.
- Raising and handling exceptions, asking, returning, and treating an account are tasks/goals under the responsibility of specific agents

JaCaMo+Exception+Accountability: background

- JaCaMo integrate three different programming platforms: agents (Jason [Bordini et al., 2007]), environments (CArtAgO [Ricci et al., 2009]), and organizations (Moise [Hübner et al., 2007])

JaCaMo+Exception+Accountability: background

- The organizational model has three dimensions:
  - The **structural dimension**: it specifies roles, groups, and links between roles in the organizations
  - The **functional dimension**: it encompasses one or more schemas that elicit how the organizational goals are decomposed into sub-goals and how these sub-goals are grouped in coherent missions
  - The **normative dimension**: it distributes the responsibilities to roles, by specifying role permissions and obligations for missions
- The organizational infrastructure is part of the environment through a set of dedicated organizational artifacts
- The organizational specification is translated into a normative program (NOPL [Hübner et al., 2009]), which is interpreted by the organizational artifacts

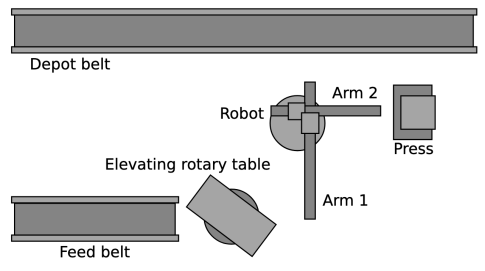
JaCaMo+Exception+Accountability: platform integration

- In order to include exception handling and accountability, we worked at three levels:
  - **Specificaton level**: We enriched the specification of an organization with the specification of a set of *notification policies* (for exceptions) and *accountability agreements*
  - **Normative level**: We extended the normative program in NOPL to issue the obligations related to the notification policies and accountability agreements
  - **Infrastructure level**: We enriched the organizational infrastructure with the functionalities needed by agent to raise or handle exceptions and to provide or treat accounts

JaCaMo+Exception+Accountability: Specification level

We extended the specification level with:

- **Notification policies** to specify when an exception occurs, how notify it (*raising goal*), and how handling it (*handling goal*)
- **Accountability agreements** to specify when an account may be requested (*requesting goal*), how to report it (*accounting goal*), and how treat it (*treatement goal*)



A production cell for metal plates inspired to [Lewerentz and Lindner, 1995]

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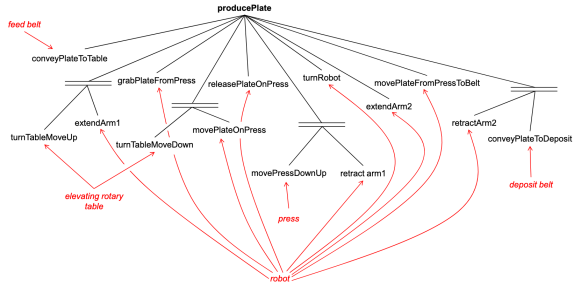

Scheme of the functional decomposition in JaCaMo

JaCaMo+Exception+Accountability: Specification level

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```
<notification-policy id="npMotor" target="turnTableMoveUp"
        condition="scheme_id(S) &amp;amp; failed(S,turnTableMoveUp)">
    <exception-specification id="exMotor">
        <exception-argument id="motorNumber" arity="1" />
        <raising-goal id="notifyStoppedMotorNumber" />
        <handling-goal id="motorFix">
            <plan operator="sequence">
                <goal id="scheduleTableMotorFix" />
                <goal id="pauseProduction" />
            </plan>
        </handling-goal>
    </exception-specification>
</notification-policy>
```

Notification policy for exception handling

JaCaMo+Exception+Accountability: Specification level

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```
<accountability-agreement id="aa1" target="conveyPlateToTable" condition="true">
    <account-template id="stock">
        <account-argument id="availablePlates" arity="1" />
        <requesting-goal id="requestRemainingStock" />
        <accounting-goal id="notifyRemainingStock" />
        <treatment-goal id="slowDownProduction"
            when="account(stock,_,[availablePlates(N)]) &amp;
                ( N &lt;= 10 &amp; N &gt; 0 )" />
        <treatment-goal id="stopProduction"
            when="account(stock,_,[availablePlates(0)]) " />
    </account-template>
</accountability-agreement>
```

Accountability agreement for accounting

JaCaMo+Exception+Accountability: Agent level

We extended the agent level with:

- **goalFailed(G)**, by which an agent can signal the failure of a goal
- **raiseException(E, Args)**, by which an agent can raise an exception with a list of arguments (template)
- **giveAccount(A, Args)**, by which an agent can report an account with a list of possible arguments (template), upon request
- **goalReleased(G)**, by which an agent can release a failed (organizatinal) goal

These are used in a Jason agent program

JaCaMo+Exception+Accountability: Availability

- It is available here: `https://di.unito.it/moiseexceptions`
- It is available here: `https://di.unito.it/moiseaccountability`

Indeed, very soon in a branch of the official Moise distribution in a single extension!

More information in
[Baldoni et al., 2021a, Baldoni et al., 2021b, Baldoni et al., 2022, Tedeschi, 2021] for exception handling and in
[Baldoni et al., 2021c, Baldoni et al., 2021d, Baldoni et al., 2023] for accountability

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