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Accountability and Multiagent Organizations: From Concepts to Software Engineering

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(Article begins on next page)

Accountability and Multiagent Organizations

from Concepts to Software Engineering

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Dipartimento di Informatica



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Accountability?

A constellation of views

- *Social Sciences*: Ethnomethodology, Garfinkel, Rawls & David;
- *Political Sciences*: Anderson, Government of Canada, Grant & Keohane, Melvin Dubnick, Bovens;
- *Tort Law*: Goldberg and Zipursky;
- *Social Psychology*: Tetlock;
- *Philosophy*: Robert Nozick, Stephen Darwall;
- ... *many* ...

Accountability → Blame

1. **Post factum:** who is to blame for an act or an error that has occurred;

Accountability and Blame [Dubnick, 2013]

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2. **Pre factum:** who is blameworthy for errors not yet occurred.

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Types of blame cultures:

1. Legalistic
2. Stigma
3. Giri
4. Prejudicial

Robert Nozick (philosopher) distinguishes 'moral pulls' from 'moral pushes':

- **moral push**: emphasizes the person who is the subject of a moral life, their character and motivation
- **moral pull**: emphasizes the entities in the world outside of the moral agent as a source of value that generates obligations which exert a pull on the agent

Accountability and Setting [Dubnick, 2013]

Accountability as deriving from the combination of moral pushes and pulls:

Setting	Moral Pulls	Moral Pushes
Legal	Liability	Obligation
Organizational	Answerability	Obedience
Professional	Responsibility	Fidelity
Political	Responsiveness	Amenability

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HOW DO THESE RELATE TO BLAME?

Accountability and Blame

- **liable**: legally blameworthy (if not satisfying obligation)
- **answerable**: blameworthy (if not obedient)
- **responsible**: be in control so that you will not be blamed by those who trust you
- **responsive**: that adapts (amenable: capable of submission)

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ALWAYS INTER-PERSONAL

In moral philosophy terms: **second-personal** rather than **first-** (me thinking of myself) or **third-personal** (coming from the outside) [Darwall, 2006]

Example (public administration)

Co-existing accountability systems in the
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Sometimes seen as systems for managing expectations.

Many understandings ...

Accountability ...

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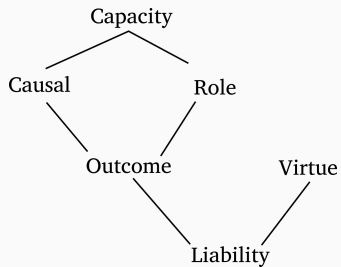
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6. **Liability:** Smith should take responsibility for his victims' families' losses, but his employer will probably be held responsible for them as Smith is insolvent and uninsured.

Ontology of Responsibilities



In MAS literature:

- “one being responsible for a task” is understood as “the one who carries out the task” (survey [Feltus, 2014], see also [Yazdanpanah and Dastani, 2016])
- Goal decomposition and distribution (e.g. [Boissier et al., 2013])
- In [Baldoni et al., 2019b] we see a responsibility as an agent being “a recipient” for (and being moved by) some institutional event

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Why at all accounting for something?

Example: Can the Dean sleep quiet dreams?

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OBLIGATIONS/SANCTIONS
(Blame culture approach)

- **Lack of capability:** an agent who does not have the capability to do something will not do it even if obliged (and sanctioned upon failure);
- **Convenience:** a rational agent that finds a sanction more acceptable than satisfying an obligation to do a task, that does not comply with the agent's goals, will not abide by the obligation (and will not explain the reasons).

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Blame is not enough:

Sanction does not add capability nor it increases the responsabilization of the agents.

Well-known in Sociology

[Durkheim, 1893], [Parsons, 1968], [Garfinkel, 1967], etc.

- obligation insufficient to explain social action,
- an agent acts **voluntarily** if the act is **desirable** for the agent
- Normative sanction often has little consequence on the agent and no consequence at the society level

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- Software modularized in terms of subgoals that are assigned to the agents
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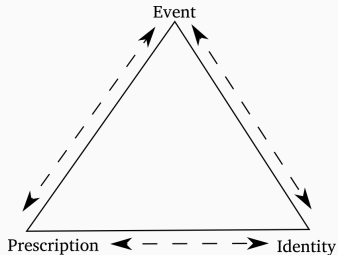
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- Little problem ...

Triangle Model of responsibility [Schlenker et al., 1994]

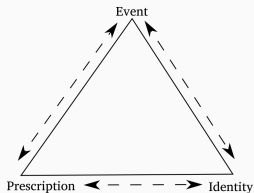


Schlenker et al.

An individual perceives a responsibility when the links are strong: identity-event, event-prescription, prescription-identity.

INSIDE THE AGENT

Triangle Model of responsibility: Example



identity: Luca the doorman,
prescription: should open the door,
event: the bell rings.

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DEPARTMENTS FEEL RESPONSIBLE

Each Dept. verifies compliance

Answer is: YES!

A student complains to the Dean about some private data being exposed by a Department

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The Dean is blamed (and sanctioned)

And then?

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- How to gather information for solving the problem and avoiding similar situations in the future?
- A lot of information about the Department's organization is available but the one we need is hidden and must be found.

- Lack of an adequate representation
- Accountability hidden into some kind of collective responsibility – sometimes called “many hands problem”.
- Governance of the system and its functioning as a whole are compromised.

Punishment vs Remedy

Tort Law [Goldberg and Zipursky, 2010]

Legal wrong: VIOLATION OF A DIRECTIVE

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Criminal Law

- **simple directive:**
For all x , x shall not A
- empowers the state to hold wrongdoers accountable
- **Accountability** → **punishment**

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Tort Law

- **relational directive:**
For all x and for all y , x shall not do A to y
- **empowers private parties** to initiate proceedings designed to hold tortfeasors accountable
- **Accountability:** the successful victim will have the right to exact a remedy, and courts will apply **principles of remedy**

Responsibility is not enough
Something is missing

Ethnomethodology, a Radical View, H. Garfinkel [**Garfinkel, 1967**]

Distinctive feature of Garfinkel's approach to social order:

“people organize their actions and interactions as concerted by making them 'accountable' - that is, reciprocally recognizable. Thus, social activities are performed as observable and reportable phenomena. [...]

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WHY?

A student complains to the Dean ...

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Action is not devised so as to be reportable.

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Agents do not share the same conception of legitimacy.

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Agents do not share the same conception of legitimacy.

Information is hidden, not always accessible.

Let's introduce Accountability

1. *Accountability implies agency.*

Without the qualities to act “autonomously, interactively and adaptively,” i.e. with agency, there is no reason to speak of accountability because we would be talking of a tool, and tools cannot be held accountable [Simon, 2015].

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2. *Accountability requires but is not limited to causal significance.*

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3. *Accountability does not hinder autonomy.*

It makes sense because of autonomy in deliberation [Anderson, 1981, Schlenker et al., 1994, Suchman, 1997, Chopra and Singh, 2014].

4. *Accountability requires control.*

Control is the capability, possibly exercised indirectly via other agents, of bringing about events [Marengo et al., 2011] (omissions, i.e. not acting, can be seen as non-achievements).

5. *Accountability requires observability.*

In order to make correct judgments, a forum must be able to observe the necessary relevant information.

7. *Accountability requires a mutually held expectation.*

It is a directed social relationship that serves the purposes of sense-making and coordination in a group of interacting parties, all of whom share an agreement on how things should be done [Garfinkel, 1967, Suchman, 1997, Anderson, 1981].

Both parties must be aware of such a relationship.

8. *Accountability is rights-driven.*

One is held accountable by another who, in a certain context, has the claim-right to ask for the account [Darwall, 2013, Grant and Keohane, 2005].

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Responsibilization through Accountability

- **Explicitly represent:** who is accountable of what and towards whom, and conditions of the claim-right;
- **Legitimacy:** Agents accept accountabilities.

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- How to gather information for solving the problem and avoiding similar situations in the future?
By requesting the proof
- It is always clear and accepted who should return accounts to whom and when: sort of additional explicit “infrastructure”

Normative dimension

it creates mutual expectations on the behavior of the involved agents; it captures the *legitimacy*, for the account taker, of asking (and the *availability* of the account giver to provide) an account (the standing of the account taker to demand an account).

Structural dimension

it concerns the *capability* to produce an account; for being held to account about a process, an agent must exert control over the same process and must have proper awareness of the situation it accounts for, possibly by relying on other agents.

Organization Engineering?

Accountability acceptance exposes the responsibilities agents perceive (previously hidden):

- enables reasoning
- increases system robustness

On legitimate requests:

- **Lack of capability:** the agent will either not play the role or will explain its lack of skill when asked;
- **Convenience:** agents will explain the conflict between their goal and the assigned task.
- **Behave up to the standard:** agents can be asked proofs also when goals are achieved!
Certification, when “how things are done” matters.

From Blame to Self-regulation

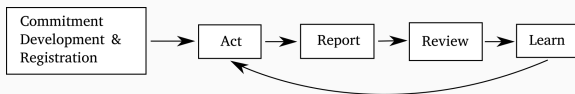


Figure 1: A general scheme for accountability frameworks inspired by [Auditor General of Canada , 2002], appeared in [Baldoni et al., 2018d].

Account is more constructive than blame

Accountability for robustness

Robustness: an important property of software systems

Sys. and Soft. Eng. Vocabulary ISO/IEC/IEEE 24765

Robustness as the degree to which a system or component can function correctly in the presence of invalid inputs or stressful environmental conditions.

Robustness refers to a system property

A property of a system is robust if it is **invariant with respect to a set of perturbations** [Alderson and Doyle, 2010].

- **reliability** as robustness to component failure
- **efficiency** as robustness to lack of resources
- **scalability** as robustness to change to the size and complexity of the system as a whole
- **modularity** as robustness to structured component rearrangements
- **evolvability** as robustness of lineages to changes on long time scales

Robustness: the role of feedback

The availability of feedback is seen as crucial in gaining robustness [Alderson and Doyle, 2010].

Feedback

A piece of **information**, some facts that are obtained **retroactively**, that **objectively concern** an execution of interest, and **that are passed** from one component to another.

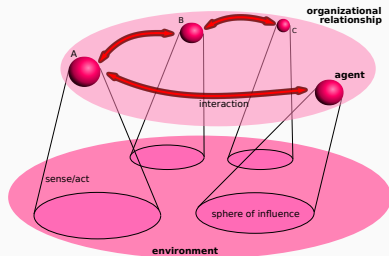
Significance and quality of feedback

are crucial in making a system robust: [Alderson and Doyle, 2010].

- only information that is **functional** to the desired kind of robustness
- only information that comes from **reliable source**

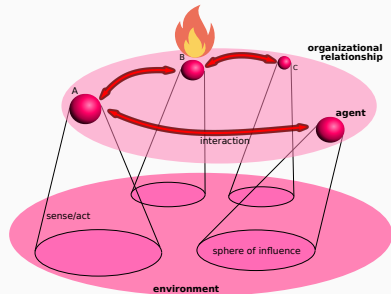
Multiagent Organizations

- “An organization provides a structure of constraints that allow a system consisting of many parts to act as a whole, with the aim of achieving goals that otherwise would not be achievable (or not as easily)” [Elder-Vass, 2011]
- **Norms** (rules, protocols, etc.) to define what is expected of each agent
- **Sanctions** as deterrents to **prevent** norm violation



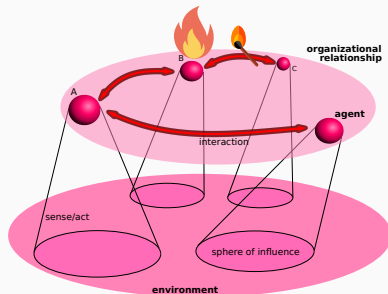
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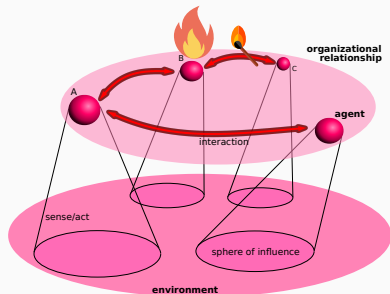
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- The agent may have tried its best to do what expected, but something which is not under its control might hinder the achievement



Perturbations

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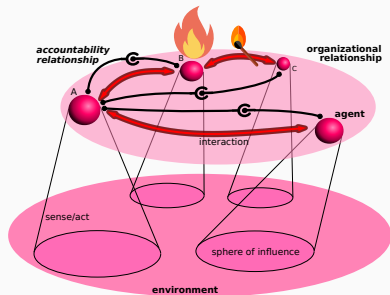
Broader problem

No structured way for collecting and propagating information about encountered situations

Robustness

When a system meets a perturbation it needs **to reconfigure**. To this aim:

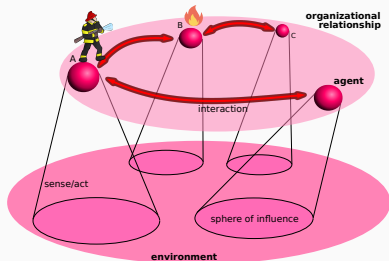
1. the agents need the means for: understanding who is entitled to ask what to whom
2. the information of interest must be asked to an informed source and must be delivered in the right format
3. the information will be delivered to whom is equipped with the right abilities and will be entitled to perform certain tasks, needed to cope with the situation



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Fragility in MAS: the role of feedback

- The **agents' autonomy** is an enabler of the system's adaptability, which is crucial to achieve robustness
 - However, adaptability requires the system to be equipped with the ability to produce proper feedback, propagate it, and process it, so to enable the selection and enactment of behavior that is appropriate to cope with the situation
- The **normative system** enables the exploitation of the agents' autonomy, creating expectations on their activities, which is crucial to achieve system robustness
 - However, agents may fail the expectations (the obligations). Whenever sanctions are not accompanied by feedback and feedback handling mechanisms, they do not provide a means that support robustness

- The current design methodologies for MAS fall short in addressing robustness in a systematic way at design time.

Accountability

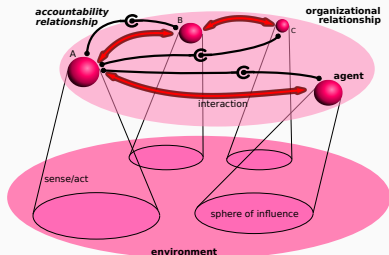
We exploit the notion of **accountability**

[Garfinkel, 1967, Grant and Keohane, 2005, Dubnick and Justice, 2004, Baldoni et al., 2016, Baldoni et al., 2019a] as a mechanism for building feedback/reporting frameworks, similarly to what is often done in human organizations

[Sustainable Energy for All Initiative, , Zahran, 2011].

Accountability as a means for robustness in MAS

- We claim that **account** and **accountability** are the crucial tools for making organizations more **robust**
- In the **human world/organizations** accountability it provides the means to address recurring and systemic issues, and to incorporate lessons learned into future activities



A conceptual model for the accountability

Conceptual Model

A **conceptual model** is a visual representation of conceptual classes or real-situation objects in a domain.

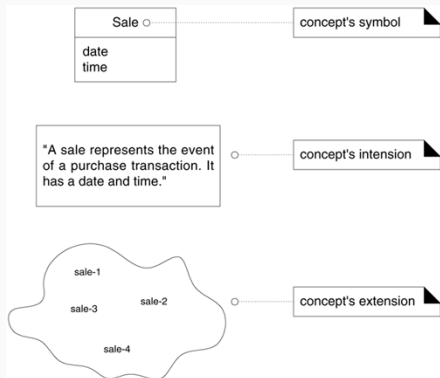
Applying UML notation, a conceptual model is illustrated with a set of class diagrams in which no operations (method signatures) are defined.

It provides a conceptual perspective. It may show:

- **conceptual classes**
- **associations** between conceptual classes
- **attributes** of conceptual classes

Conceptual class

- **Symbol** words or images representing a conceptual class
- **Intension** the definition of a conceptual class
- **Extension** the set of examples to which the conceptual class applies.

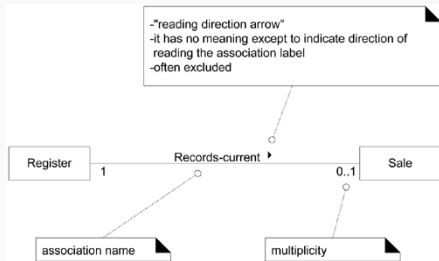


©C. Larman. Applying UML and patterns. Addison Wesley

Professional, 2004.

Association

An association is a **relationship** between classes (more precisely, instances of those classes) that indicates some meaningful and interesting connection.

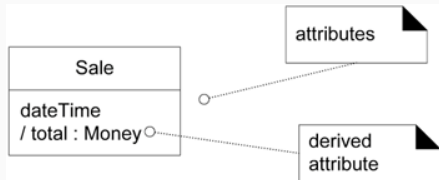


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Professional, 2004.

Attribute

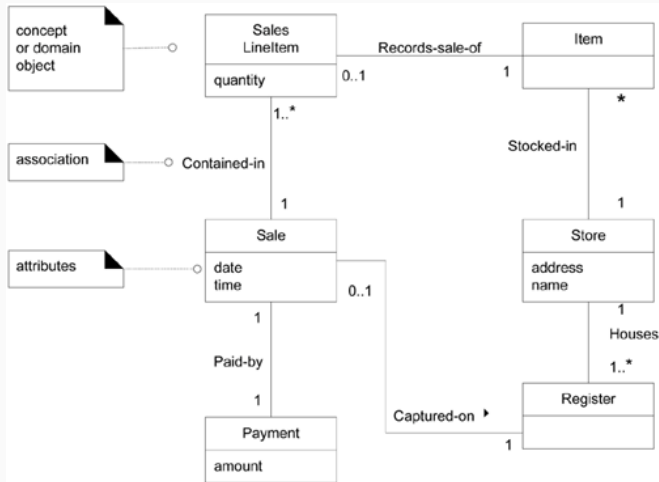
An attribute is a logical data value of an object.



©C. Larman. Applying UML and patterns. Addison Wesley

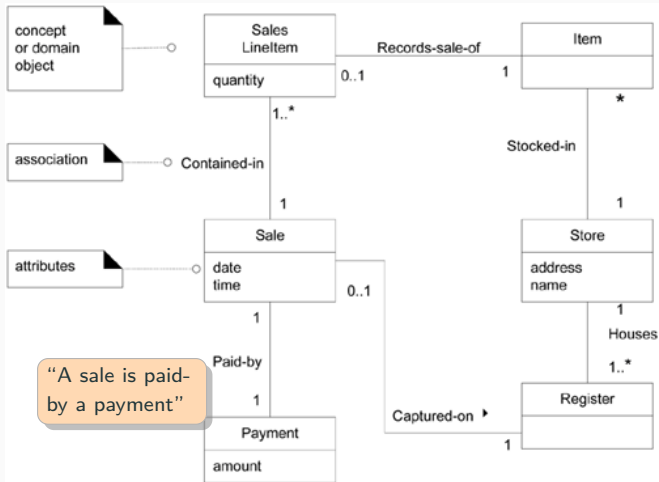
Professional, 2004.

An example of conceptual model



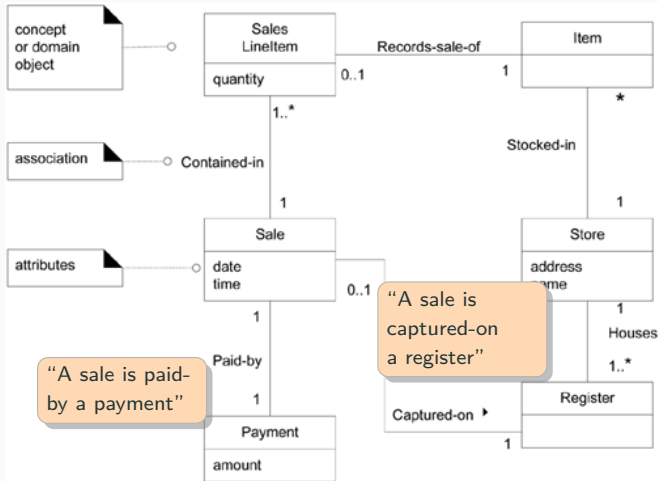
©C. Larman. Applying UML and patterns. Addison Wesley Professional, 2004.

An example of conceptual model



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An example of conceptual model



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Task, Agent, and Responsibility

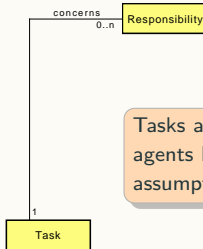
Accountability and
Organizations

Responsibility

An organization can be seen as a distribution of responsibilities [Wooldridge, 2002, López y López and Luck, 2003, Dignum et al., 2004, Hubner et al., 2007]

Task, Agent, and Responsibility

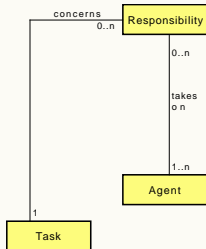
Accountability and
Organizations



Tasks are distributed among
agents by way of responsibility
assumptions

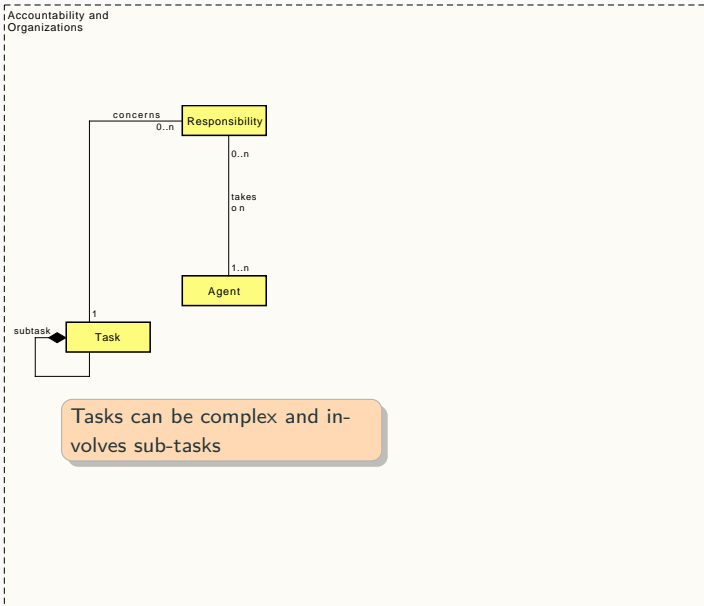
Task, Agent, and Responsibility

Accountability and Organizations

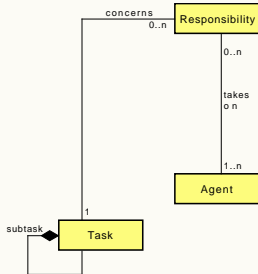


An agent is part of the organization only when it explicitly takes on the responsibility that concerns some task

Task, Agent, and Responsibility



Accountability and
Organizations

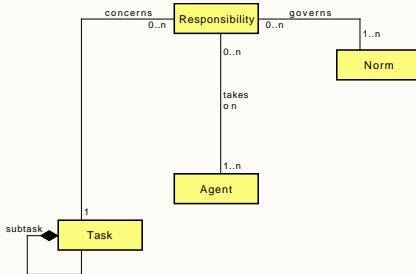


Norm

Norms yield obligations, prohibitions, and authorizations about tasks

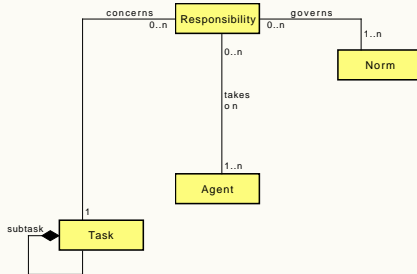
Norms are used to describe the ideal behavior of the agents in terms of their responsibilities

Accountability and Organizations



Answerability and Accountability

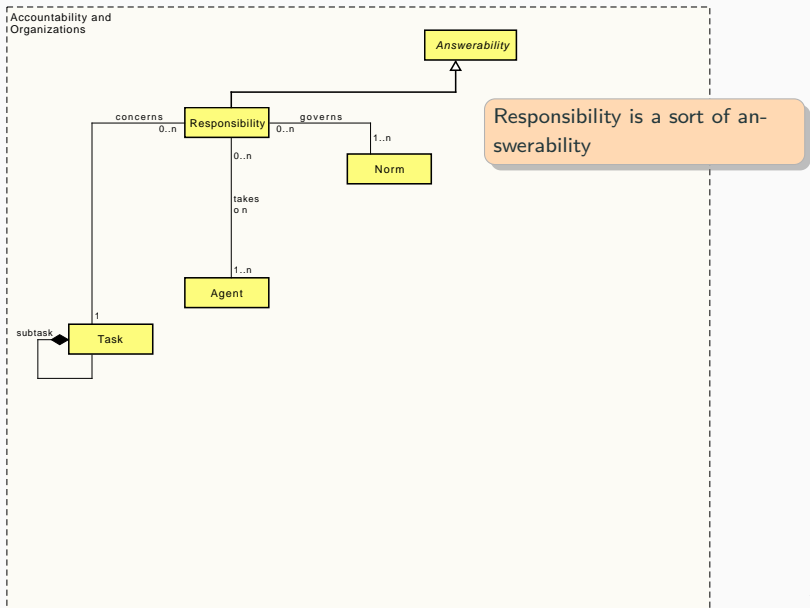
Accountability and Organizations



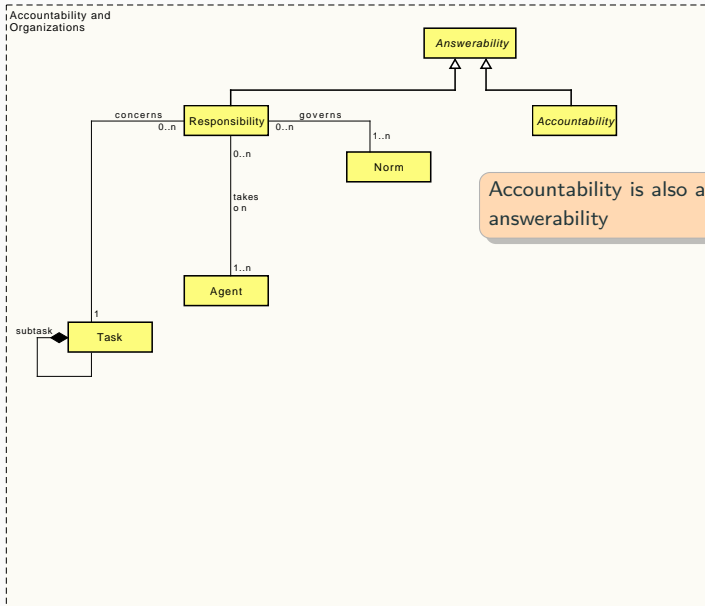
Answerability

Answerability is the ability to provide an answer

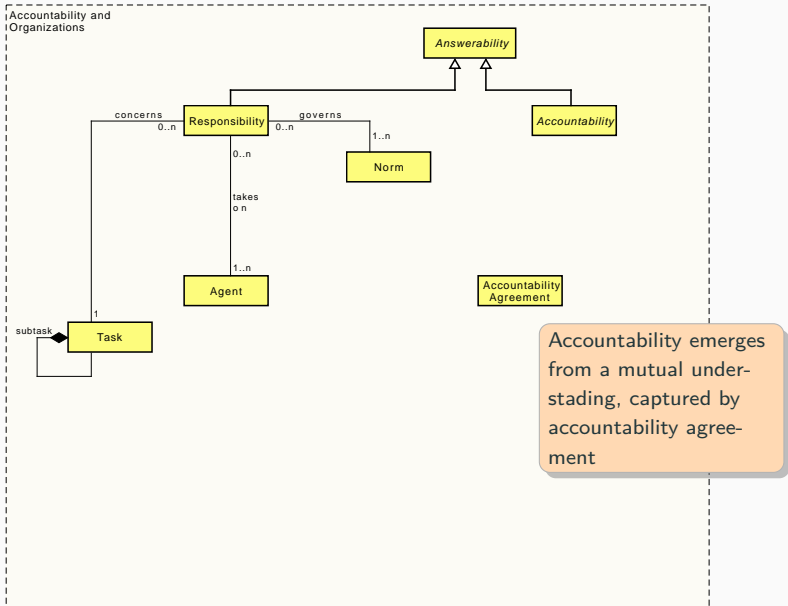
Answerability and Accountability



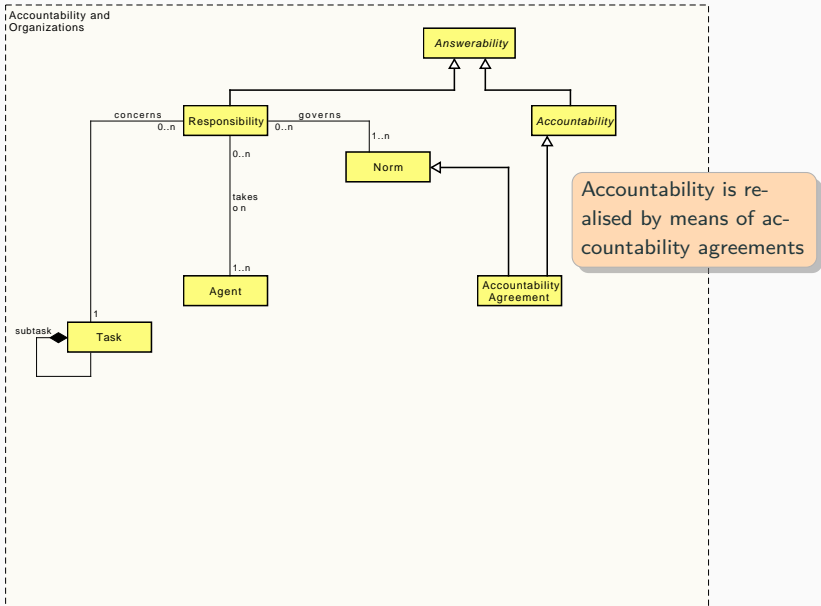
Answerability and Accountability



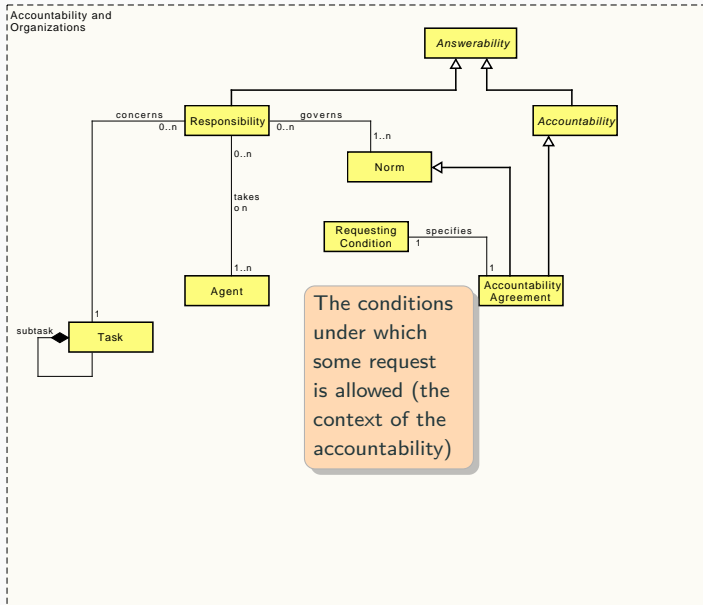
Accountability agreement



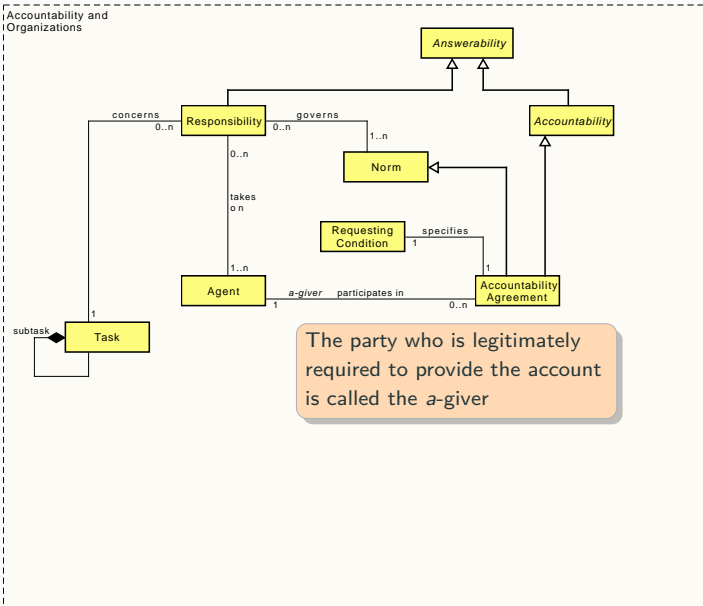
Accountability agreement



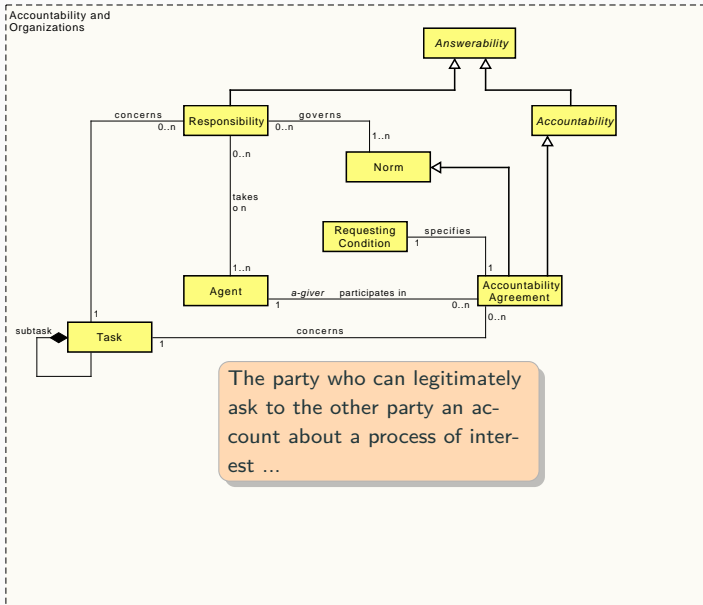
Accountability agreement



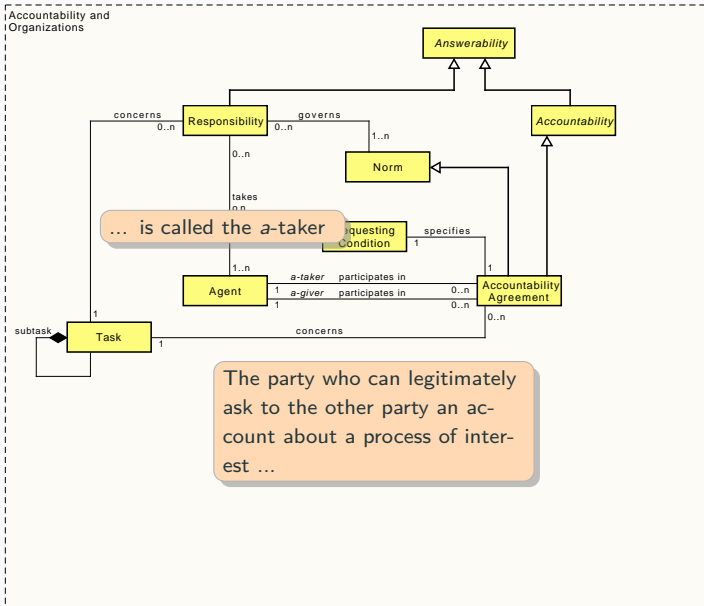
Accountability agreement



Accountability agreement



Accountability agreement



How to model the two dimension of the accountability?

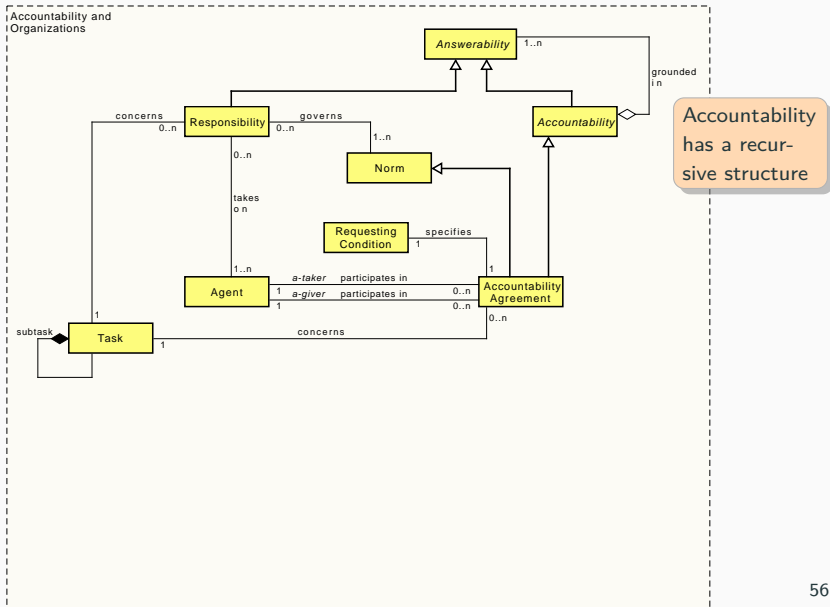
A relationship between two parties:

- One of the parties (the “**account taker**” or *a-taker*) can legitimately ask, under some agreed conditions, to the other party an **account** about a process of interest
- the other party (the “**account giver**” or *a-giver*) is legitimately required to provide the account to the a-taker

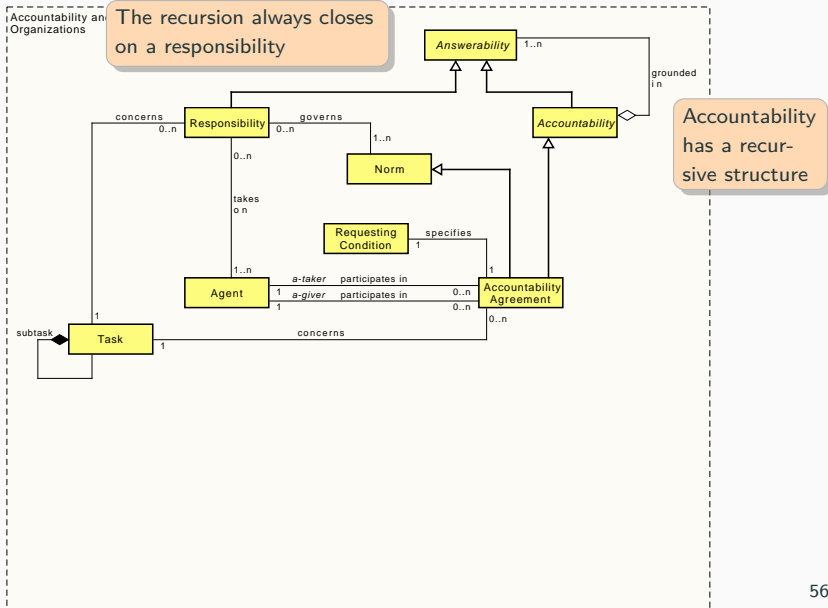
The two dimensions of accountability

1. **Normative dimension** → Legitimacy of asking and availability to provide accounts
2. **Structural dimension** → For being accountable about a process, an agent must have control over that process and have awareness of the situation it will account for

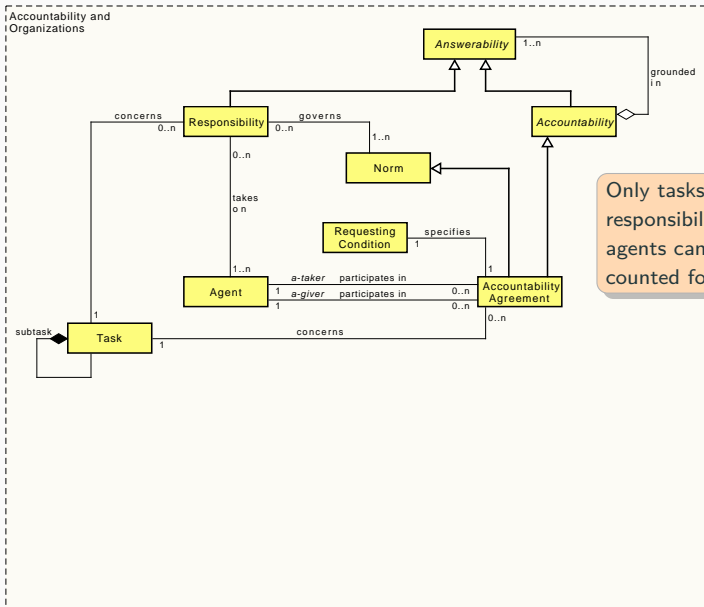
Accountability: the decorator pattern



Accountability: the decorator pattern

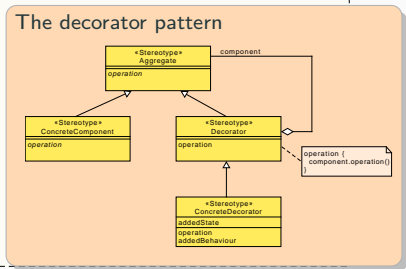
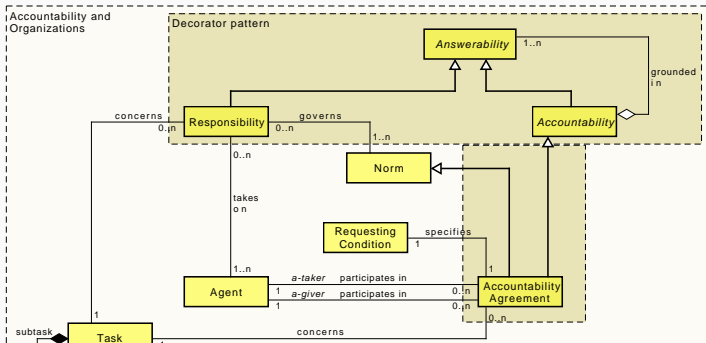


Accountability: the decorator pattern

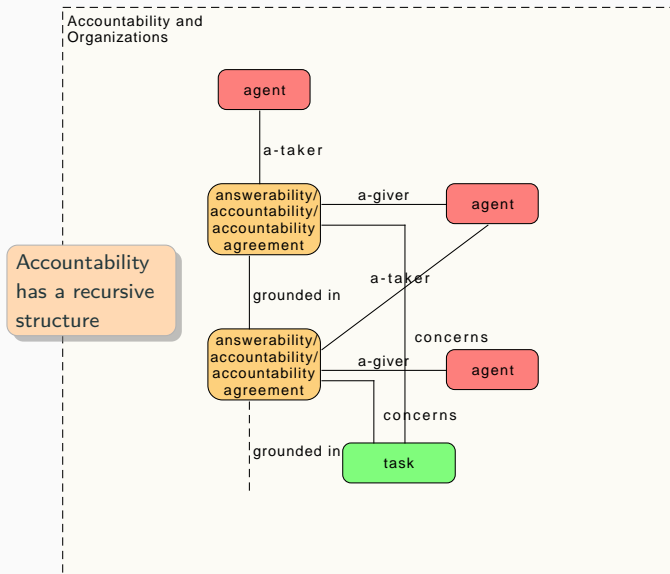


Only tasks under the responsibility of some agents can be accounted for

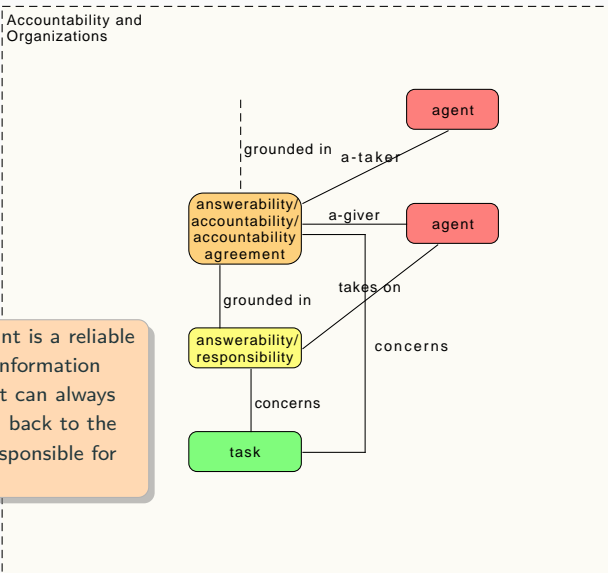
Accountability: the decorator pattern



From the point of view of instances

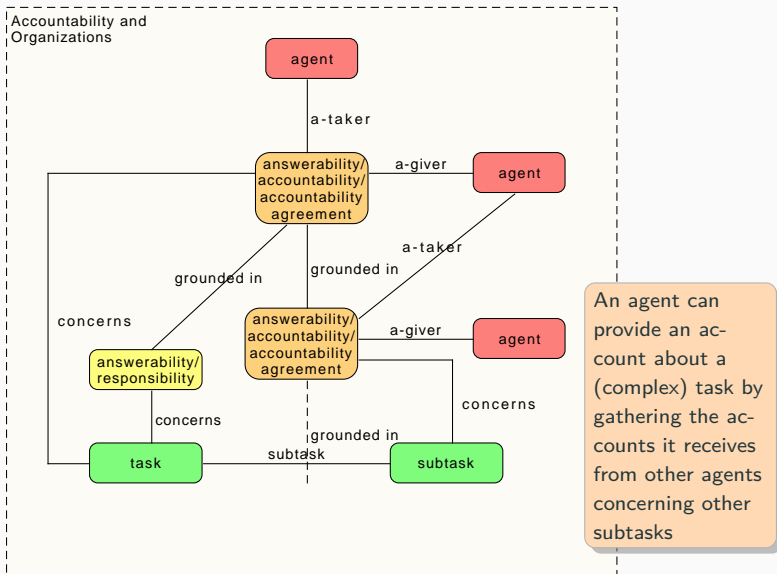


From the point of view of instances

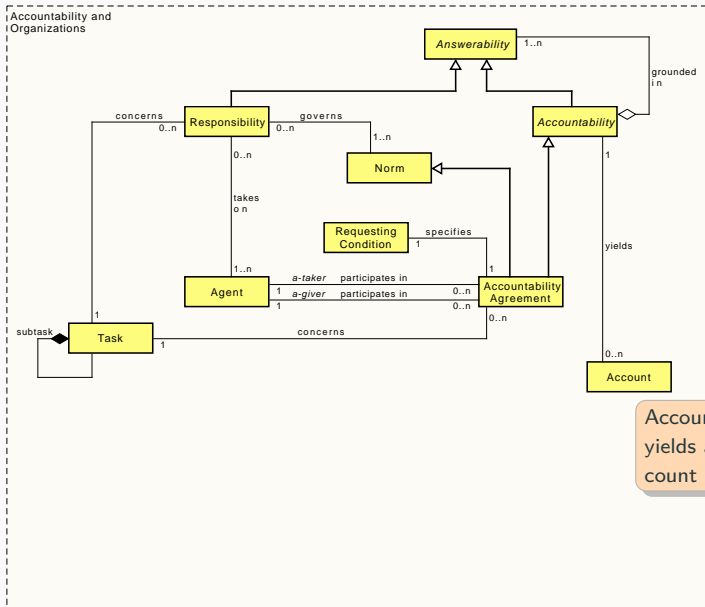


An account is a reliable piece of information because it can always be traced back to the agents responsible for that task

From the point of view of instances

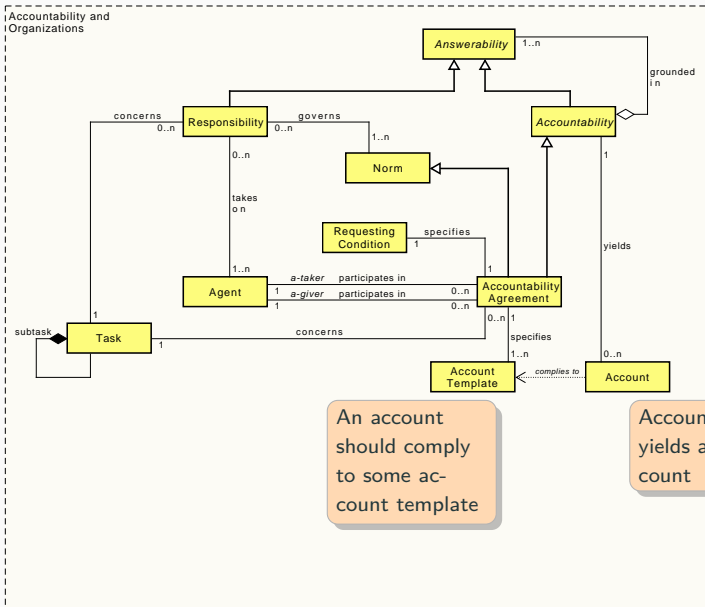


Account and Account Template

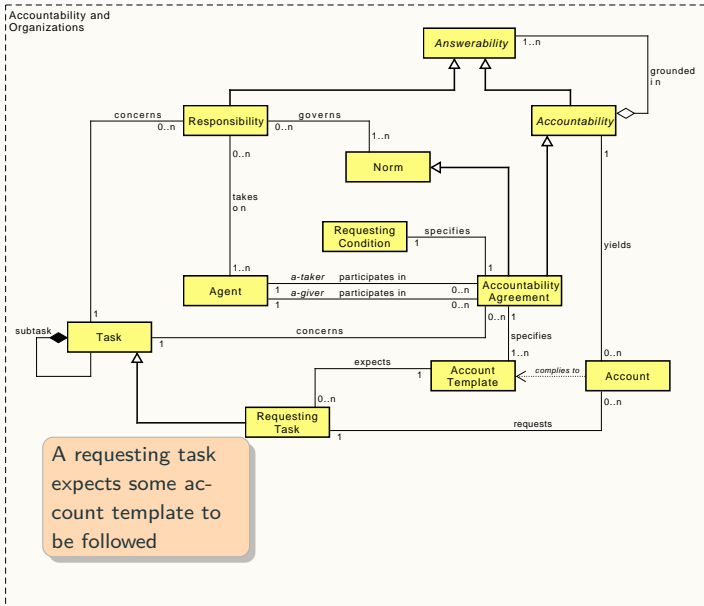


Accountability yields an account

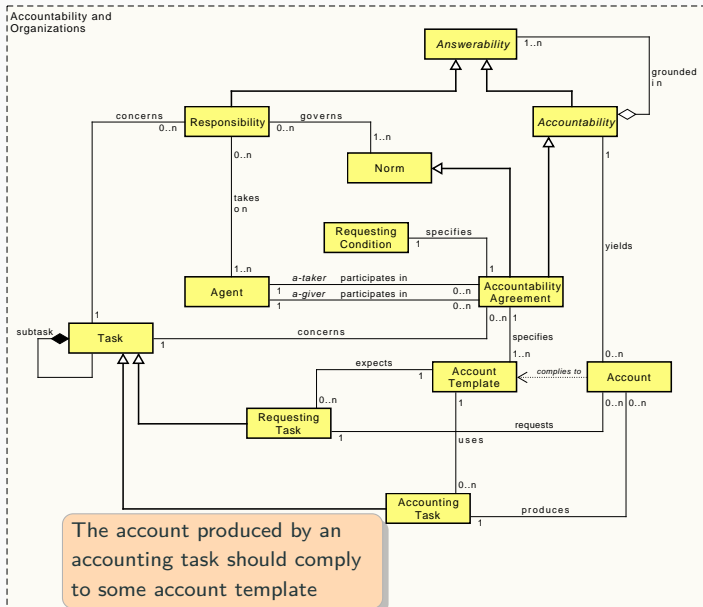
Account and Account Template



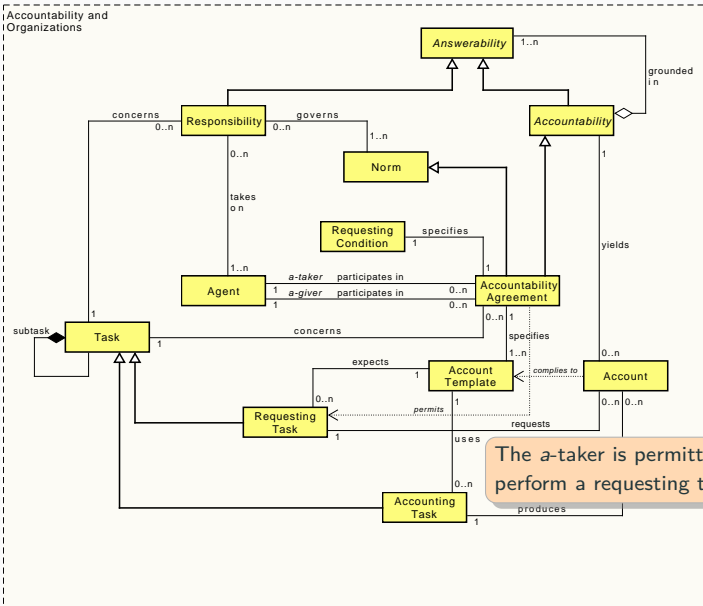
Requesting and Accounting Task



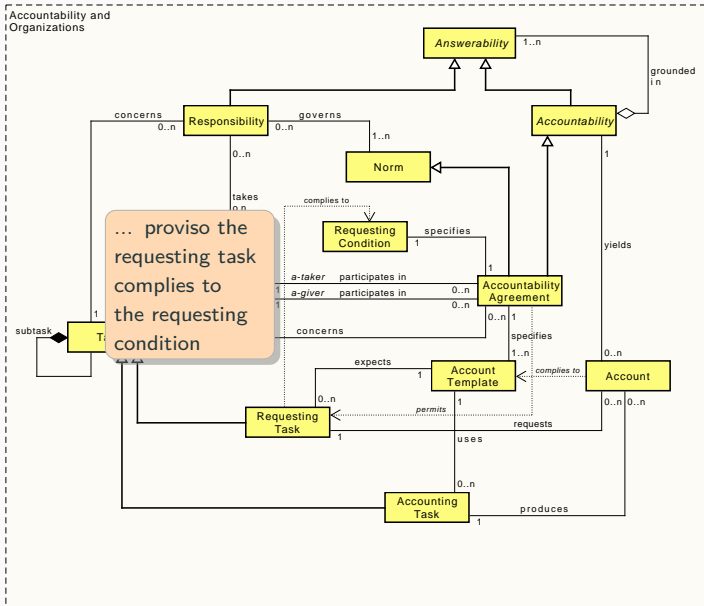
Requesting and Accounting Task



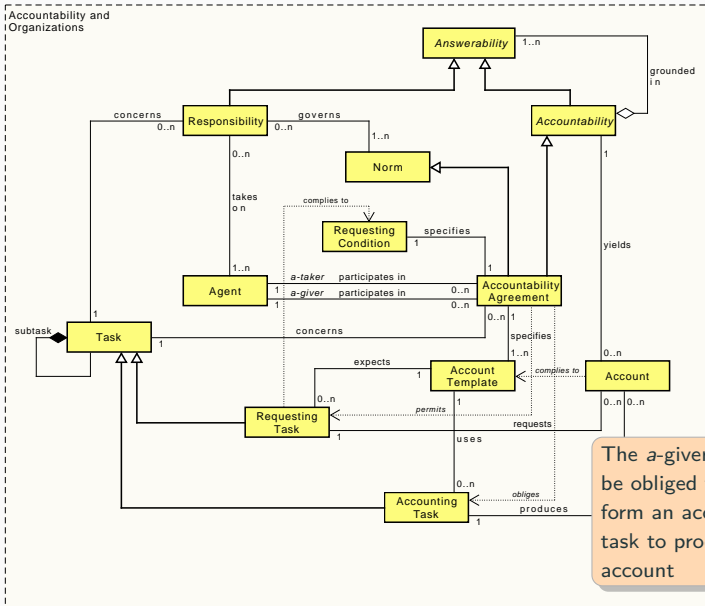
Requesting and Accounting Task



Requesting and Accounting Task

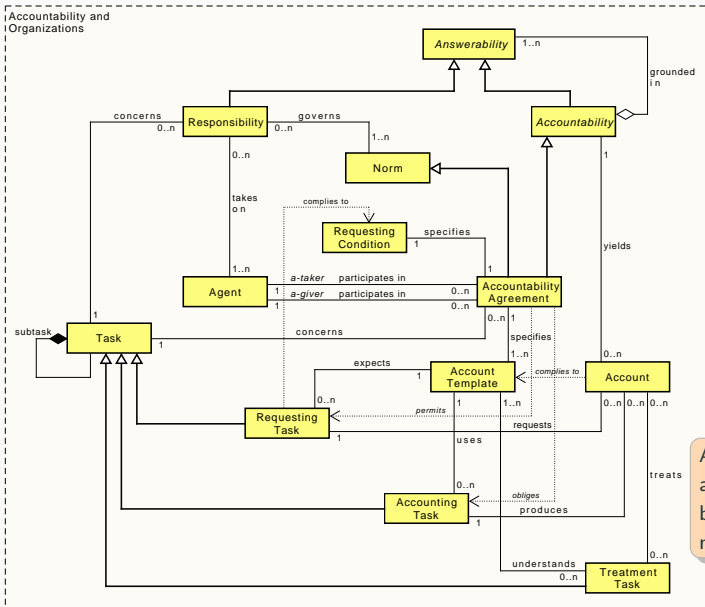


Requesting and Accounting Task



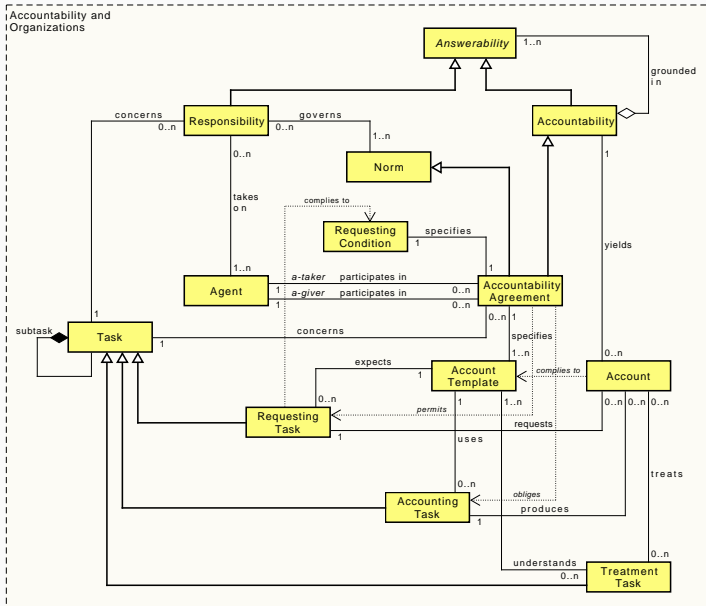
The *a-giver* may be obliged to perform an accounting task to produce an account

Treatment Task



Accounts are treated by treatment tasks

Organizational accountability: a conceptual model



Experimenting Accountability in JaCaMo

- A very short introduction to JaCaMo
- How JaCaMo is extended to accommodate accountability
- Patterns for using accountability in agent programming
 - Information gathering
 - Context-aware adaptation
 - Exception Handling

A very short introduction about JaCaMo

- JaCaMo is a Multi-Agent Oriented Programming (MAOP) platform
- it aims at programming systems by providing a seamless integration of three dimensions:

- **Organization** via **Moise** [Hübner et al., 2010]
- **Agent** via **Jason** [Bordini et al., 2007],
- **Environment** via **CARTAgO** [Ricci et al., 2009],

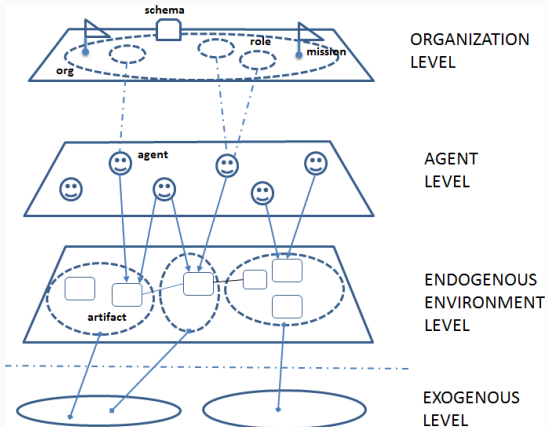
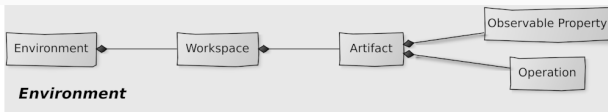


Figure 2: MAOP levels [Boissier et al., 2019]

Environment dimension



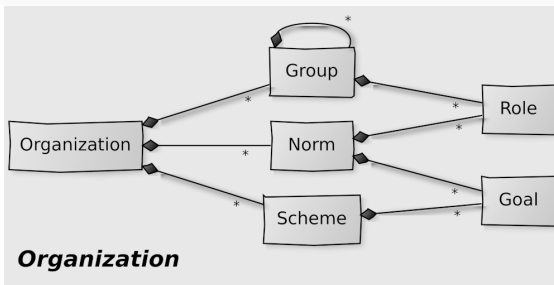
Simplified conceptual view (A&A meta-model [Omicini et al., 2008])

Simple artifact
program:

```
public class Counter extends Artifact {  
    void init(int initialValue) {  
        defineObsProperty("count", initialValue);  
    }  
  
    @OPERATION void inc() {  
        ObsProperty prop = getObsProperty("count");  
        prop.updateValue(prop.intValue()+1);  
    }  
}
```

From [Boissier et al., 2019]

Organization dimension



Simplified Conceptual View (Moise meta-model [Hübner et al., 2009])

Excerpts from organisation program:

```
<structural-specification>
```

```
<role-definitions>
```

```
<role id="auctioneer" />
```

```
<role id="participant" />
```

```
</role-definitions>
```

```
<group-specification id="auctionGroup">
```

```
<roles>
```

```
<role id="auctioneer" min="1" max="1"/>
```

```
<role id="participant" min="0" max="300"/>
```

```
</roles>
```

```
</group-specification>
```

```
</structural-specification>
```

Structural spec.

```
<functional-specification>
```

```
<scheme id="doAuction">
```

```
<goal id="auction">
```

```
<argument id="Id" />
```

```
<argument id="Service" />
```

```
<plan operator="sequence">
```

```
<goal id="start" />
```

```
<goal id="bid" ttf="10 seconds" />
```

```
<goal id="decide" ttf="1 hour" />
```

```
</plan>
```

```
</goal>
```

```
<mission id="mAuctioneer" min="1" max="1">
```

```
<goal id="start" />
```

```
<goal id="decide" />
```

```
</mission>
```

Functional spec.

```
<normative-specification>
```

```
<norm id="n1" type="permission"
```

```
role="auctioneer"
```

```
mission="mAuctioneer" />
```

```
<norm id="n2" type="obligation"
```

```
role="participant"
```

```
mission="mParticipant" />
```

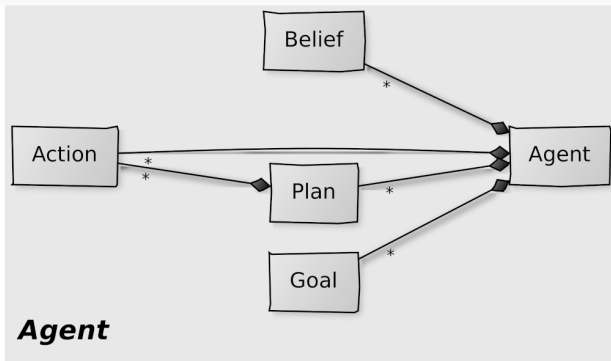
```
</normative-specification>
```

Normative spec.

```
norm n1 : plays(A, auctioneer, G) ->
forbidden(A,n1,plays(A,participant,G),
'forever!')
```

program in NPL

Agent dimension



Simplified Conceptual View (Jason meta-model [Bordini et al., 2007]):

Simple Agent Program:

```
happy(bob). // initial belief
!say(hello). // initial goal
/* Plans */
+!say(X) : happy(bob) <- .print(X).
// ...
```

example bob.asl

```
+happy(A) <- !say(hello(A)).
+!say(A) : not today(weekday) <- .print(X); !say(X).
+!say(X) : today(weekday) <- .print("stop").
-happy(A) : .my_name(A) <- .drop_intention(say(_)).
```

example carl.asl

Agent's plans for obligations

Obligation to commit to a mission

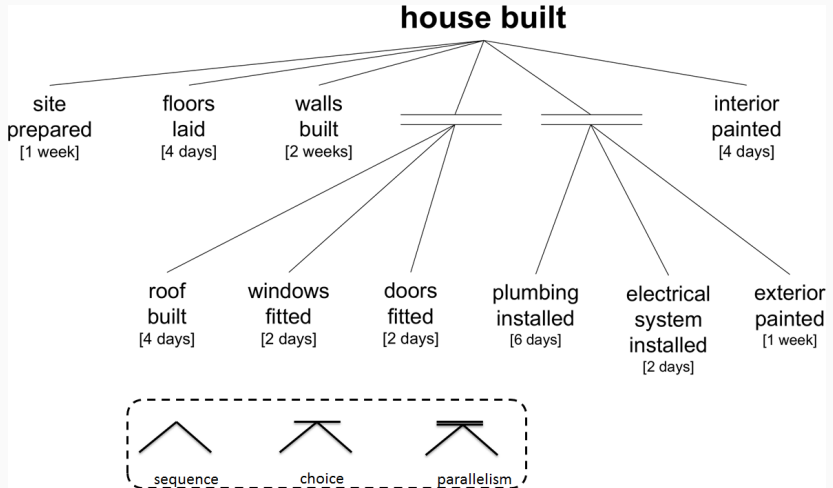
```
+obligation(Ag, Norm, committed(Ag, Mission, Scheme), Deadline)
  : .my_name(Ag)
  <- .print("I am obliged to commit to ", Mission);
     commit_mission(Mission, Scheme).
```

Obligation to a goal

```
+obligation(Ag, Norm, achieved(Sch, Goal, Ag), Deadline)
  : .my_name(Ag)
  <- .print("I am obliged to achieve goal ", Goal);
     !Goal[scheme(Sch)];
     goal_achieved(Goal, Sch).
```


The building house example

Functional decomposition



Extending JaCaMo for Accountability

- Changes mostly concern the **organization specification**; i.e., the Moise component
- Changes are **as conservative as** possible (when no accountability relationship is specified, we fall back to standard JaCaMo)
- Changes satisfy three needs:
 - **specify accountability agreements** within an organization
 - translate accountability agreements into a **corresponding body of norms**
 - give agents the capability of **producing accounts** and **marking goals** not only as *achieved*, but also as *failed* or *released*

Specifying Accountability Agreement

- The functional spec. is extended to include an XML tag for accountability agreement

```
Accountability Agreement id: aa1
concerns: u
can request when: r

Account Template:
  requesting goal: TASK
  accountability goal: TASK
  must account with: arguments
  treatment goal: TASK
  must treat when: condition
```

```
<supervision-strategy id="strParcel">
  <accountability-agreement id="aaParcel">
    <target id="reachDestination" />
    <request-template id="reqStock">
      <requesting-condition value="delay" />
      <goal id="requestDelayReason" />
    </request-template>
    <account-template id="accParcel">
      <goal id="reportDelayReason" />
      <account-argument id="reason" arity="1" />
      <account-argument id="closedRoads" arity="1" />
    </account-template>
  </accountability-agreement>
  <treatment-policy id="tpParcel">
    <treatment-condition value="true" />
    <goal id="updateMap" />
  </treatment-policy>
</supervision-strategy>
```

Generating norms from agreements

- New normative facts, such as:
 - `requestingGoal(G)`
 - `accountabilityAgreement(id, target)`
 - `requestTemplate(id, condition, requesting goal)`
 - `accountTemplate(id, accounting goal)`
 - `accountArgument(account template id, functor, arity)`
 - ...
- New norms and rules, such as:
 - `enabled(S,G) :-`
`goal(_, G, dep(or,PCG), _, NP, _) & requestingGoal(G) &`
`requestTemplate(RT,Condition,G) & Condition & NP \== 0 &`
`any_satisfied(S,PCG).`

Generating accounts

- This extension touches the artifact representing organizational schema
- New operations are made available to the agents:
 - `giveAccount()`: generates an account as an observable property within the artifact (publicly accessible)
 - `goalFailed()`: marks a goal as failed: the organizational goal cannot proceed
 - `goalReleased()`: marks a goal as released: even though the goal has not been satisfied (it may be even failed), the goal is no longer required (usually after an appropriate treatment), and hence the organizational goal can be resumed

Where to find the software...

- JaCaMo home page (standard version by Boissier et al.)
<http://jacamo.sourceforge.net/>
- JaCaMo for accountability
<http://di.unito.it/moiseaccountability>
- JaCaMo for exception handling
<https://sourceforge.net/projects/moise-exceptions/>

Note: No need to install standard JaCaMo first, our projects are self-contained

How does accountability come into play while programming agents?

Three basic programming patterns can be exploited for capturing a variety of situations

- Information gathering
- Context-aware adaptation
- Exception handling

Information gathering

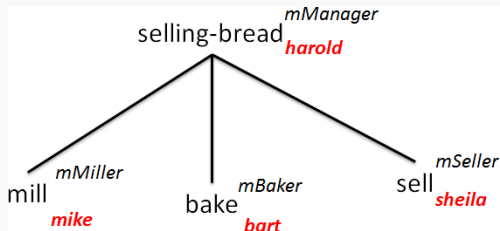
Objective: let an agent gather information at runtime to complete its goals

```
+!organizational-goal
  : <account missing>
  <-
    goalAchieved(requestForAccount);
    .wait(500);
    !organizational-goal.
```

```
+!organizational-goal
  : <account ready>
  <-
    <do something useful>
    goalAchieved(organizational-goal).
```


Information gathering for decision making

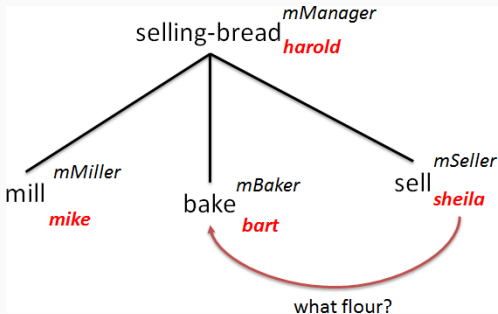
Scenario: Harold is the owner of an organization produces and sells bread



- Sheila can decide, autonomously, the price of the bread she sells.
- She can fix a reasonable price on her own, or she can exploit infos about the production process; e.g., is the flour “standard” or organic?

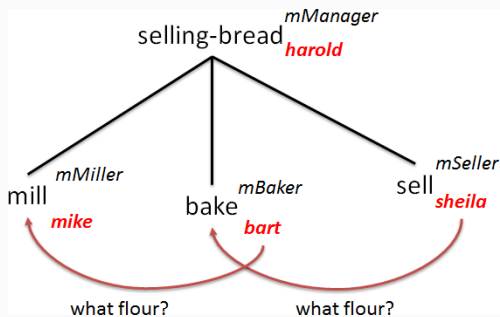
Information gathering for decision making

Relying on an accountability relationship, Sheila could ask an account to Bart about the bake goal.



Information gathering for decision making

In turn, Bart could ask an account to Mike about goal `mill`.



Conceptually, the accountability agreement between Sheila and Bart is:

```
Accountability Agreement id: aa1
  concerns: bake
  can request when: true

Account Template:
  requesting goal: requestFlourType
  accountability goal: notifyFlourType
  must account with: flourType
```

The *a-taker* and *a-giver* agents are designated by including goal `requestFlourType` in a Sheila's mission, and goal `notifyFlourType` in a Bart's mission, respectively

Information gathering for decision making

Looking at the XML specifying the organization...

```
<supervision-strategy id="strWhatFlour">
  <accountability-agreement id="aal">
    <target id="bake" />
    <request-template id="reqWhatFlour">
      <requesting-condition value="true" />
      <goal id="requestFlourType" type="achievement"/>
    </request-template>
    <account-template id="accFT">
      <goal id="notifyFlourType" />
      <account-argument id="flourType" arity="1" />
    </account-template>
  </accountability-agreement>
</supervision-strategy>
...
<mission id="mBaker" min="1" max="1">
  <goal id="bake"/>
  <goal id="notifyFlourType"/>
</mission>
<mission id="mSeller" min="1" max="1">
  <goal id="sell"/>
  <goal id="requestFlourType"/>
</mission>
...
```

Between Bart and Mike a similar agreement exists

Information gathering for decision making

Applying the pattern to Sheila's program

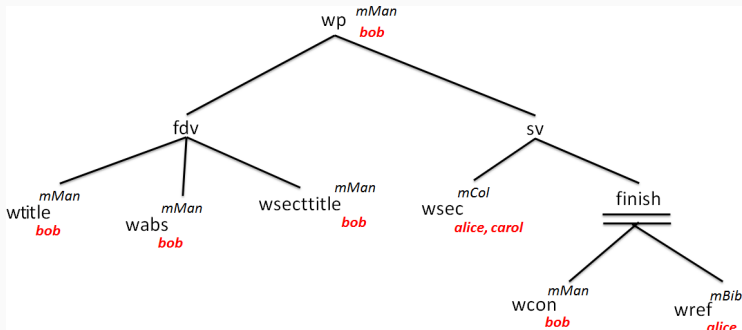
```
+!sell :
  not account(flourType(N))
  <-
  .print("I need more info to fix the price!");
  goalAchieved(requestFlourType);
  .print("asked for the type of flour");
  .wait(500);
  !sell.
```

```
+!sell :
  account(flourType(N))
  <-
  if (N == "bio"){
    .println("Bio flour set high price at 9.00 euros");
  }
  else {
    .println("Standard flour set low price at 2.00 euros");
  }.
}
```

DEMO LIVE

Information gathering for integration

Scenario: Bob, Alice and Carol cooperate for writing a paper (see JaCaMo documentation)

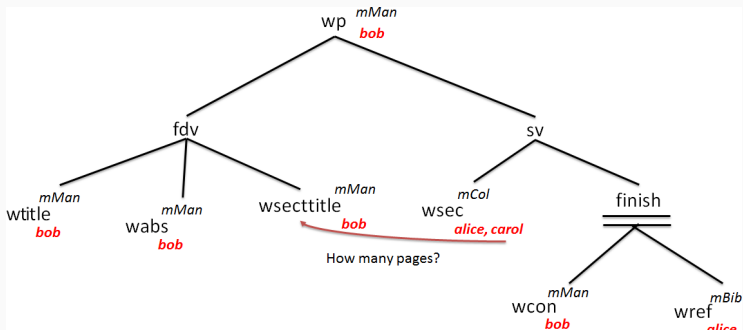


Alice and Carol are both asked to achieve goal `wsec`. However, they achieve the goal in different ways:

- Carol needs to know how many pages must be written
- Alice writes as many pages as she can

Information gathering for integration

Let us assume the following agreement exists



Conceptually, the following accountability agreement is specified between Carol and Bob

```
Accountability Agreement id: aa2
```

```
  concerns: wsecttitle
```

```
  can request when: true
```

```
Account Template:
```

```
  requesting goal: requestSectionLength
```

```
  accountability goal: notifySectionLenth
```

```
  must account with: pageNumber
```

Information gathering for integration

Applying the pattern to Carol's program

```
+!wsecs[scheme(S)]
: not account(pageNumber(N))
<-
  .print("asking for page number");
  goalAchieved(requestSectionLength);
  .wait(500);
  !wsecs[scheme(S)].

+!wsecs[scheme(S)]
: account(pageNumber(N))
<-
  .print("writing ", N, " pages for scheme 2 ",S,"...").
```

DEMO LIVE

Context-aware adaptation

Objective: Acquire contextual conditions that are of some interest and that require a special treatment when they occur.

The treatment is part of the organization specification

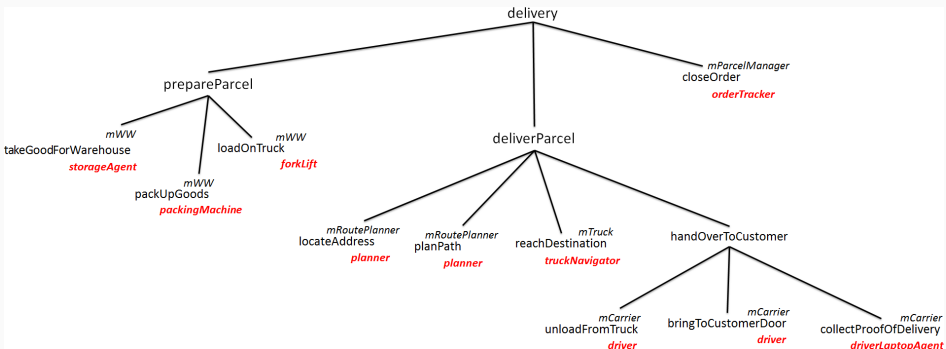
⇒ *A proper obligation will be issued*

```
+newInterestingSituation
: <some-context>
<-
  goalAchieved(requestForAccount).

+!treatNewInterestingSituation
: <account-about-the-situation>
<-
  <do-something-about-the-situation>;
  goalAchieved(treatNewInterestingSituation).
```

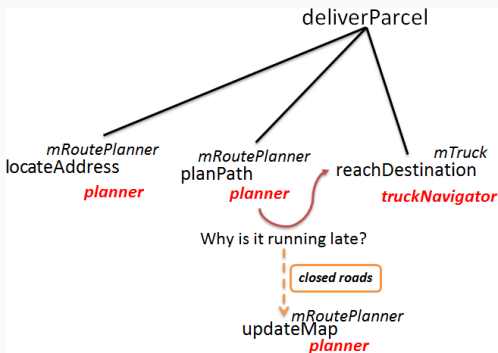
Context-aware adaptation

Scenario: The delivery of some goods involves many agents from the packaging to the shipping. *Many things can go wrong!*



Context-aware adaptation

- Reaching a destination could require longer than expected due to some closed road.
- Updating the planner's map could prevent delays in the next shipping



Conceptually, the accountability agreement is structured as follows

```
Accountability Agreement id: aaParcel
  concerns: reachDestination
  can request when: true
```

Account Template:

```
  requesting goal: requestDelayReason
  accountability goal: reportDelayReason
    must account with: reason
    must account with: closedRoads
  treatment goal: updateMap
    must treat when: true
```

Context-aware adaptation

Applying the pattern to the planner agent

```
+oblUnfulfilled(obligation(_,_,done(_,reachDestination,_),_))
  <- println("*** REQUESTING DELAY REASON ***");
    goalAchieved(requestDelayReason).

+!updateMap
  : account(closedRoads(I))
  <- println("*** ADDING CLOSED ROADS TO IGNORE LIST... ***");
    +ignore(I).
```

- **Accountability promotes adaptation/innovation:**

The planner now excludes the closed roads while planning the routes of future shipping

- **Accountability is not blame:**

Sanctioning the truck would not allow the planner to know why the delivery is delayed, future deliveries would be affected by the same problem

DEMO LIVE

Exception

Event that causes suspension of normal program execution.

[ISO/IEC/IEEE, 2010]

- The purpose of an exception handling mechanism is to:
 1. Identify when an **exception** (i.e., a *perturbation*) occurs
 2. Apply suitable **handlers**, capable of treating the exception and recover

Responsibility in Exception Handling

Exception handling is a matter of **responsibility distribution**:

1. Always involves two parties: a party that is **responsible** for raising an exception, and another party that is **responsible** for handling it
2. Captures the need for some **information/account** from the former to the latter that allows coping with the exception

Exception handling can be built upon accountability relationships

Accountability and Exception handling

- For the exception handling purpose, the account is naturally given automatically as soon as a perturbation occurs
- The request for an account is implicit (the a-taker may not even observe the perturbation so it could not ask for an account)

A change of perspective

Terminologically

- a-giver raises an exception: **exception raiser**
- a-taker handles an exception: **exception handler**
- an account is mapped into the **raised exception**

Conceptually

```
Accountability Agreement id: aa1
  concerns: u
  can request when: r
```

```
Account Template:
  requesting goal: TASK
  accountability goal: TASK
  must account with: arguments
  treatment goal: TASK
  must treat when: condition
```

```
Recovery Strategy id: rs
  Perturbation:
    affected goal: u
    type: failed|warning|...
```

```
Notification Policy:
  throwing goal: TASK
  exception spec: arguments
```

```
Handling Policy:
  handling goal: TASK
  enabled when: condition
```

A change of perspective

Terminologically

- a-giver raises an exception: **exception raiser**
- a-taker handles an exception: **exception handler**
- an account is mapped into the **raised exception**

Conceptually

Accountability Agreement id: aa1

concerns: u
can request when: r

Account Template:

requesting goal: TASK
accountability goal: TASK
must account with: arguments
treatment goal: TASK
must treat when: condition

Recovery Strategy id: rs

Perturbation:

affected goal: u
type: failed | warning | ...

Notification Policy:

throwing goal: TASK
exception spec: arguments

Handling Policy:

handling goal: TASK
enabled when: condition

*The occurrence of a perturbation is associated
with an implicit request for account*

A change of perspective

Terminologically

- a-giver raises an exception: **exception raiser**
- a-taker handles an exception: **exception handler**
- an account is mapped into the **raised exception**

Conceptually

```
Accountability Agreement id: aa1
concerns: u
can request when: r
```

```
Account Template:
  requesting goal: TASK
  accountability goal: TASK
  must account with: arguments
  treatment goal: TASK
  must treat when: condition
```

```
Recovery Strategy id: rs
Perturbation:
  affected goal: u
  type: failed | warning | ...
```

```
Notification Policy:
  throwing goal: TASK
  exception spec: arguments
```

```
Handling Policy:
  handling goal: TASK
  enabled when: condition
```

Providing an account amount to raising an exception

A change of perspective

Terminologically

- a-giver raises an exception: **exception raiser**
- a-taker handles an exception: **exception handler**
- an account is mapped into the **raised exception**

Conceptually

```
Accountability Agreement id: aa1
concerns: u
can request when: r
```

```
Account Template:
  requesting goal: TASK
  accountability goal: TASK
  must account with: arguments
  treatment goal: TASK
  must treat when: condition
```

```
Recovery Strategy id: rs
Perturbation:
  affected goal: u
  type: failed | warning | ...
```

```
Notification Policy:
  throwing goal: TASK
  exception spec: arguments
```

```
Handling Policy:
  handling goal: TASK
  enabled when: condition
```

*The treatment of an account corresponds to handling
the raised exception*

A change of perspective

At the normative level

- An *Accountability Agreement* yields
 - a **Permission** to request an account
 - an **Obligation** to provide an account upon request
 - in some cases, there may also be an **Obligation** to treat the account
- A *Recovery Strategy* yields
 - an **Obligation** to raise an exception upon the detection of a perturbation
 - an **Obligation** to handle the raised exception

Our JaCaMo extension needs further refinements to capture such a semantics

Generating norms from agreements

- New normative facts, such as:
 - `failureReason(F)`
 - `throwException(G, [errorCode(F)]) [artifact_id(ArtId)]`
 - `exceptionThrown(S,G,)`
 - `exceptionArgument(S,G,errorCode(F))`
 - ...
- New norms and rules, such as:
 - `enabled(S,TG) :- policy_goal(P,TG) &
notificationPolicy(P,Condition) & Condition &
goal(_, TG, Dep, _, NP, _) & NP \== 0 &
((Dep = dep(or,PCG) & (any_satisfied(S,PCG) |
all_released(S,PCG))) |
(Dep = dep(and,PCG) & all_satisfied_released(S,PCG))).`

A pattern for Exception Handling

Raising-agent's side

```
//reacting to obligation permits to mark
//an organizational goal as failed
+obligation(Ag,_,done(_,SOME_GOAL,Ag),_)
  : my_name(Ag)
  <- !SOME_GOAL;
    goalAchieved(SOME_GOAL).

// organizational goal internalized by the agent
+!SOME_GOAL
  <- INTERNAL_GOAL.

//in case the internal goal fails, also the organization
//goal fails
-!SOME_GOAL[env_failure_reason(F)]
  <-
    +failureReason(F)
    goalFailed(site_prepared)[artifact_id(ArtId)];
    .fail.

//the agent is then asked to raise an exception
+obligation(Ag,_,done(_,RAISE_EX_SOME_GOAL,Ag),_)
  : .my_name(Ag) &
    failureReason(F)
  <-
    throwException(SOME_GOAL,[errorCode(F)])[artifact_id(ArtId)];
    goalAchieved(RAISE_EX_SOME_GOAL).
```

```
Recovery Strategy id: rs1
Perturbation:
  affected goal: SOME_GOAL
  type: failed

Notification Policy:
  throwing goal: RAISE_EX_SOME_GOAL
  exception spec: F

Handling Policy:
  handling goal: HANDLING_GOAL
  enabled when: condition
```

A pattern for Exception Handling

Handling-agent's side

```
//The handling agent react to the obligation of handling  
//the exception relying on the information received  
//along with the exception itself
```

```
+obligation(Ag,_,done(_,HANDLING_GOAL,Ag),_)  
: .my_name(Ag) &  
  exceptionThrown(S,SOME_GOAL,_) &  
  exceptionArgument(S,SOME_GOAL,errorCode(F))  
<-  
<do something useful to handle the exception>
```

```
//The programmer decides how to consider the fail  
//Two alternatives:  
//[
```

```
  //The failed goal is released: no longer necessary  
  goalReleased(SOME_GOAL)[artifact_id(ArtId)];
```

```
  //OR
```

```
  //the failed goal is reset: try once more to get it done  
  resetGoal(SOME_GOAL)[artifact_id(ArtId)]
```

```
  //]
```

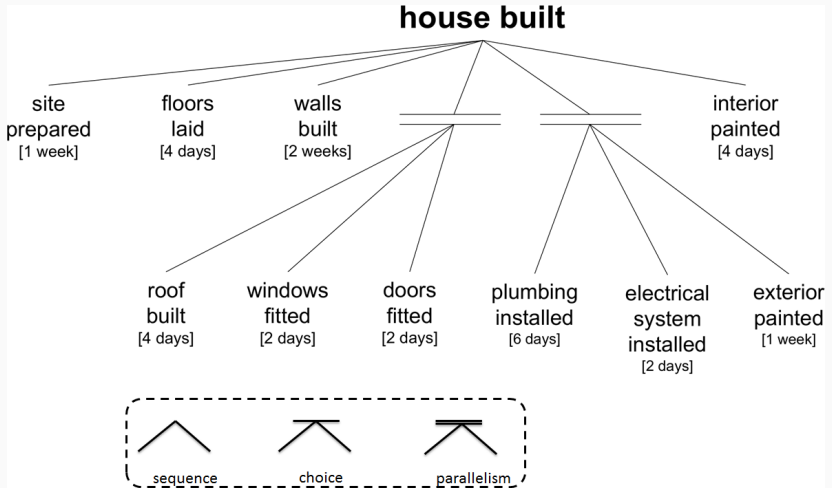
```
//the handling goal is set achieved  
goalAchieved(HANDLING_GOAL).
```

```
Recovery Strategy id: rs1  
Perturbation:  
  affected goal: SOME_GOAL  
  type: failed
```

```
Notification Policy:  
  throwing goal: RAISE_EX_SOME_GOAL  
  exception spec: F
```

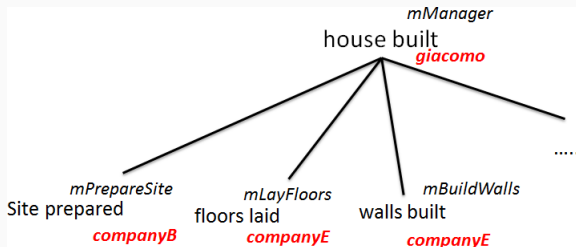
```
Handling Policy:  
  handling goal: HANDLING_GOAL  
  enabled when: condition
```

Adding exception handling to Building House

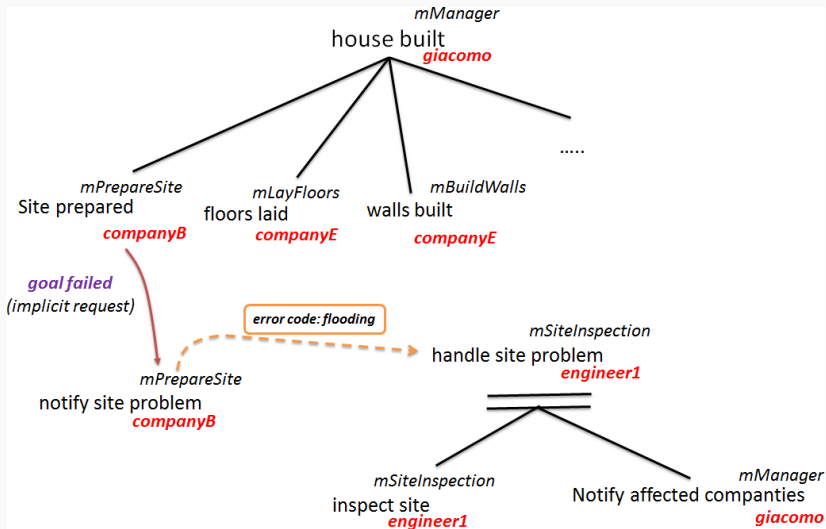


Adding exception handling to Building House

Scenario: Giacomo sets up an organization for building his house. Many companies joins the organization contributing on specific goals.



Adding exception handling to Building House



Adding exception handling to Building House

The following recovery strategy captures such a scenario

```
Recovery Strategy id: rsSitePreparation
  Perturbation:
    affected goal: site_prepared
    type: failed

  Notification Policy:
    throwing goal: site_preparation_exception
    exception spec: errorCode

  Handling Policy:
    handling goal: handle_site_problem
    enabled when: true
```

Adding exception handling to Building House

Applying the pattern to companyB (raising an exception on site_prepared)

```
+obligation(Ag,_,done(_site_prepared,Ag),_)
: my_name(Ag)
  <- !site_prepared;
     goalAchieved(site_prepared).

+!site_prepared
  <- println("Preparing site..");
     .wait(2000);
     prepareSite. // simulates the action (in GUI artifact)

-!site_prepared[env_failure_reason(F)]
: focused(ora4mas,bhsch,ArtId)
  <- println("The site is flooded due to ",F,"!");
     +failureReason(F)
     goalFailed(site_prepared)[artifact_id(ArtId)];
     .fail.

+obligation(Ag,_,done(_notify_site_preparation_problem,Ag),_)
: .my_name(Ag) &
  focused(ora4mas,bhsch,ArtId) &
  failureReason(F)
  <- println("THROWING SITE PREPARATION EXCEPTION WITH ERROR CODE ",F,"!")
     throwException(site_preparation_exception,[errorCode(F)])(artifact_id(ArtId));
     -failureReason(F);
     goalAchieved(notify_site_preparation_problem).
```

Adding exception handling to Building House

Applying the pattern to engineer1 (handling the exception)

```
+obligation(Ag,_,done(_inspect_site,Ag),_)
: .my_name(Ag) &
  focused(ora4mas,bhsch,ArtId) &
  exceptionThrown(bhsch,site_preparation_exception,_) &
  exceptionArgument(bhsch,site_preparation_exception,errorCode(flooding))
<- println("Inspecting site...");
  .wait(2000);
  performSiteAnalysis(Result);
  println("Done!");
  println("Fixing flooding...");
  .wait(2000);
  fixFlooding(Result);
  println("Done!");
  goalReleased(site_prepared)[artifact_id(ArtId)];
  goalAchieved(inspect_site).

+obligation(Ag,_,done(_inspect_site,Ag),_)
: .my_name(Ag) &
  focused(ora4mas,bhsch,ArtId) &
  exceptionThrown(bhsch,site_preparation_exception,_) &
  exceptionArgument(bhsch,site_preparation_exception,errorCode(archaeologicalRemains))
<- println("Inspecting site...");
  .wait(2000);
  delimitSite;
  println("Done!");
  println("RemovingRemains...");
  .wait(2000);
  carefullyRemoveRemains;
  println("Done!");
  resetGoal(site_prepared)[artifact_id(ArtId)].
```


Modularity via Exception Handling

Exception Handling as a means for Modularity

Exceptions and exception handling mechanisms are not needed to deal just with errors.

They are needed, in general, as a means of conveniently interleaving actions belonging to different levels of abstraction. [Goodenough, 1975]

- Exceptions allow the invoker of an operation to extend the operation domain (the set of inputs for which effects are defined), or its range (the effects obtained when certain inputs are processed)
- Increase in the generality of an operation: the appropriate “fixup” will depend on the invoker’s objectives
- **By grounding exception handling on accountability, we meet this vision!**

Outline of a General Methodology

1. Specify a (standard) JaCaMo organization:
roles, groups, functional decomposition, missions
2. Extend the organization by means *accountability relationships*:
 - **Accountability Agreements**
 - What roles may need information for its decision making process
 - What other roles may supply the needed information
 - Individuate requesting and notifying goals
 - Assign these goals to the missions of a-takers and a-givers
 - **Exception Handling** (recovery strategy)
 - What goals can fail and for what reasons (exception)
 - What countermeasures are available (exception handling goals)
 - How a perturbation should be notified (exception raising goals)
 - Assign these goals to the missions of handlers and raisers
3. Apply the patterns for programming the agents

Note: In principle both accountability agreements and recovery strategies could be defined within the same organization

CONCLUSIONS

Adopting **Accountability/Exception Handling** as a design principle induces several advantages:

- allows a designer to take into account the problem of **robustness since the early stages**, by providing a clear framework for specifying perturbations and the components dedicated to their handling
- promotes the **modularity and reuse** of software
- promotes **incrementality and integration** of new software
- maintains a **clear separation** between what it is expected the system do (i.e., functional decomposition), and how the system adapts itself to perturbations or contextual changes
- promotes **innovation** by way of the gained flexibility

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¹Accountable Trustworthy Organizations and Systems

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