JustAct: Actions Universally Justified by Partial, Dynamic Policies

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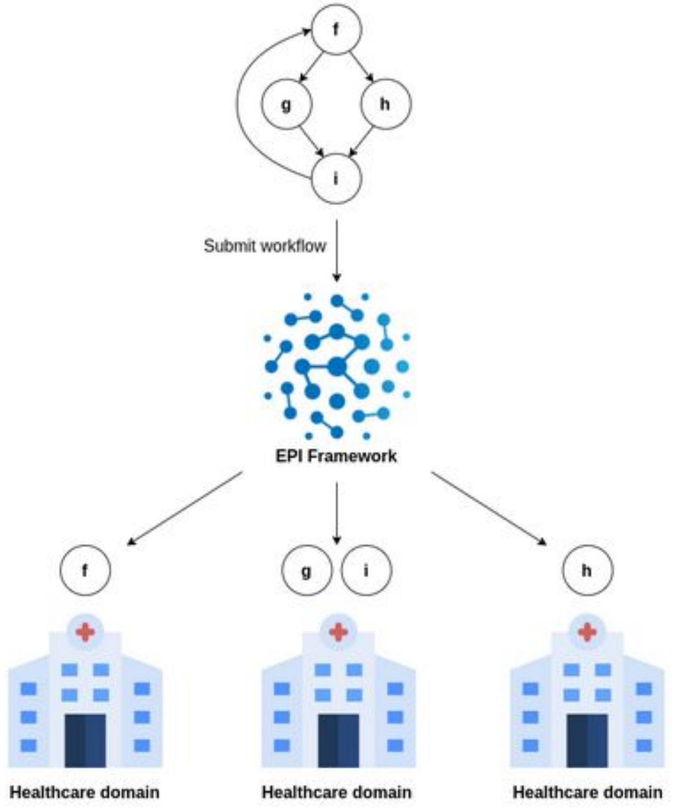
Data Exchange Systems

Data exchange systems share and process data across organisational boundaries. They are

- inherently distributed, and
- subject to complex requirements.

Example: the Brane system, orchestrating the sharing and processing of medical data.



The Role of Policy

Systems are subject to complex requirements like…

- The General Data Privacy Regulation (GDPR)
- Consortium-level agreements
- Resource-level sharing agreements

Policies capture these requirements. This affords…

- Static analysis (e.g., model-checking)
- Dynamic enforcement (e.g., monitoring)

Example Policy

Noteworthy:

- Built from expressions and rules
  ⟶ modular ⟶ (de)composable
- Models domain-specific concepts
  ⟶ complex and specific
  but not ambiguous

```
/// Stelt dat áls de `totale-commons-waarde-aangeboden` is gegeven,
/// deze waarde direct herleidbaar moet zijn tot de waarde van de
/// aangeboden producten van die Deelnemer.
///
/// Afsprakenstelsel:
/// > Deze Eurowaarde moet direct herleidbaar zijn tot
///   de commerciële waarde van de als Commons
/// > aangeboden producten, diensten en/of data(gebruik)
///   in de Producten en Diensten Catalogus.
///
/// De aanbieder kan aansprakelijk worden gehouden door
/// elke (andere) Deelnemer.

Duty totale-commons-waarde-aangeboden-herleidbaar-van-commerciele-waarde
  Holder aanbieder
  Claimant deelnemer
  Related to totale-commons-waarde-aangeboden

  // De Duty geldt voor elke aanbieder met aangeboden waarde.
  Derived from (Foreach totale-commons-waarde-aangeboden, deelnemer :
    totale-commons-waarde-aangeboden-herleidbaar-van-commerciele-waarde(
      totale-commons-waarde-aangeboden.aanbieder,
      deelnemer,
      totale-commons-waarde-aangeboden
    ) When (totale-commons-waarde-aangeboden.waarde > 0
            && totale-commons-waarde-aangeboden.aanbieder != deelnemer))

  // De Duty is geschonden als er niet genoemt is dat de
  // waarde herleidbaar is tot deze Deelnemer's aangeboden producten.
  Violated when (Exists aanbod :
    aanbod-als-commons(aanbod)
    && aanbod.aanbieder == aanbieder
    && Not(totale-waarde-herleidbaar-tot-aanbod(
                      totale-commons-waarde-aangeboden, aanbod))).
```

Example Policy

Noteworthy:

- Built from expressions and rules
  ⟶ modular ⟶ (de)composable
- Models domain-specific concepts
  ⟶ complex and specific
  but not ambiguous
- There are several useful policy langs.

```
% Statement 's1' by 'consortium' (contents of agreement at time 1)
owns(administrator, Data) :- ctl-accesses(Accessor, Data).
error :- ctl-accesses(Accessor, Data), owns(Owner, Data),
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```

Datalog$^{\neg}$

The Demands of Policy

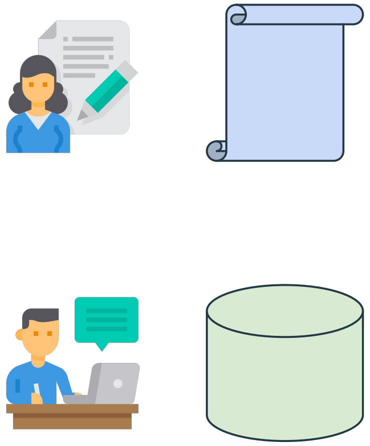
Requirements can impose significant constraints on the runtime system (e.g., data privacy regulations):

1. Policy must determine system behavior
2. Policies may change arbitrarily at runtime
3. Policies themselves may be sensitive

Each data exchange system strikes its own balance.

AMdEX project: develop generic tools for building specialised data exchange systems.

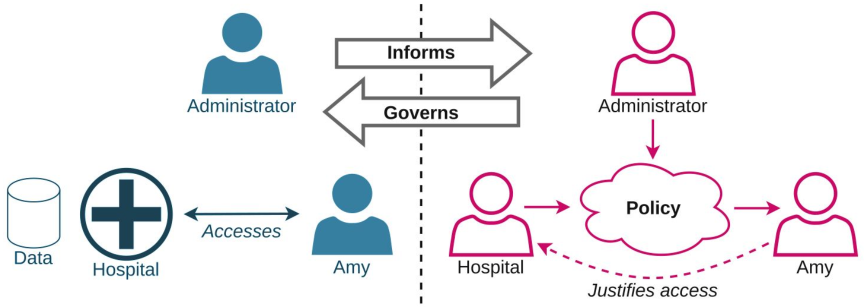
AMdEX



The Contribution

Today, we present the **JustAct** framework, which

- **Defines** the relation between policy and agents' actions and communications, but
- **Leaves undefined** the policy language and to the runtime implementation.

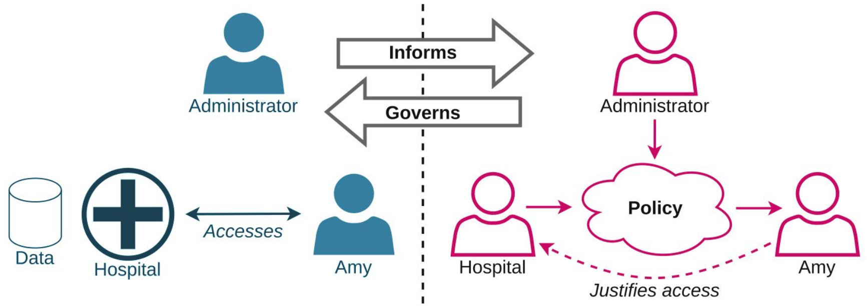


The Idea

The system consists of agents which are autonomous: each independently decides …

- Which policies they create[1] and share
- Which actions they take[2]

…

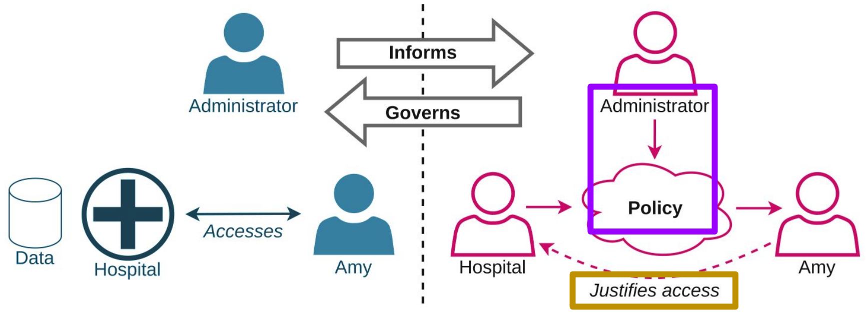


The Idea

The system consists of agents which are autonomous: each independently decides …

- Which policies they create[1] and share
- Which actions they take[2]

[1] but not every agent can **create** every policy
[2] but each action must be **justified** with a policy



Using the Framework

Precisely, our framework is…

1. A relational **abstraction** over the system
2. **Requirements** “realistically” satisfiable
3. **Guarantees** following from the requirements

Using the framework means adopting the abstraction such that the requirements are satisfied.

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1. A relational **abstraction** over the system
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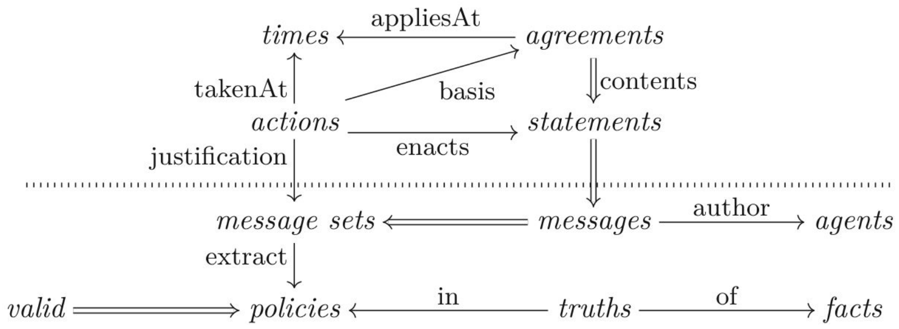
Using the framework means adopting the abstraction such that the requirements are satisfied.

Here is the abstraction, a relational ontology:



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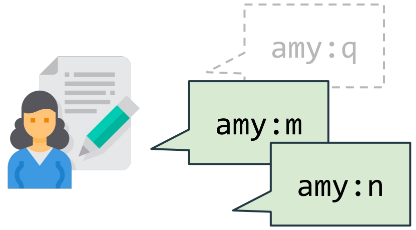
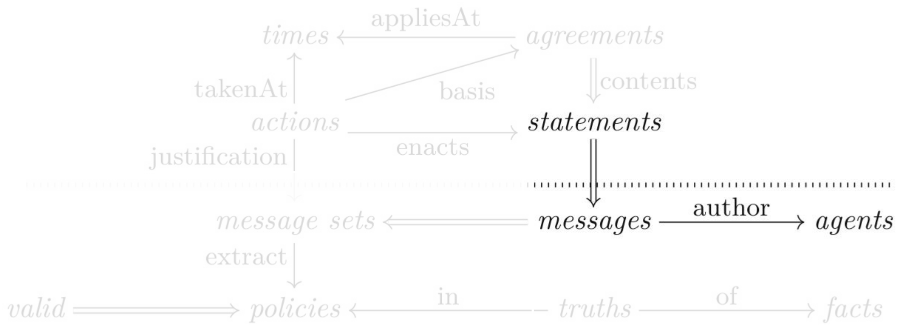
\end{tikzcd}$$

Concepts: 1/7



- Agents incrementally unfold the subset of stated messages at runtime.
- The author of each message is evident.



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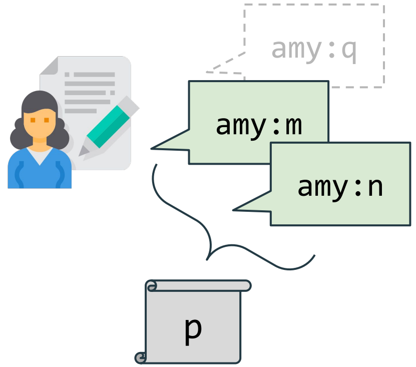
Concepts: 2/7



- Messages carry policies.
  We suggest: extract sensitive to author

- Each message set carries one policy
  We suggest: composed message-policies

- → Available policies grow with statements.

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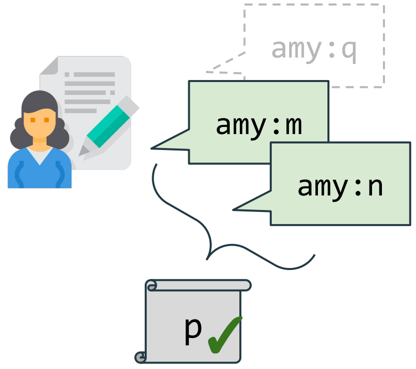
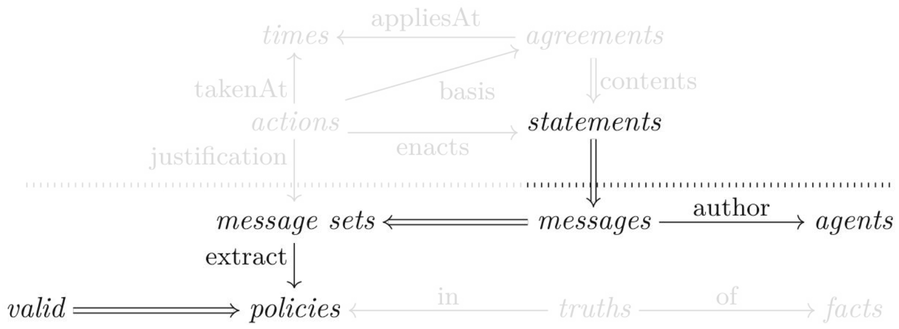
Concepts: 3/7



- Not every policy is valid (“useful”).
- We suggest: wrong message by wrong author reflected as invalidity



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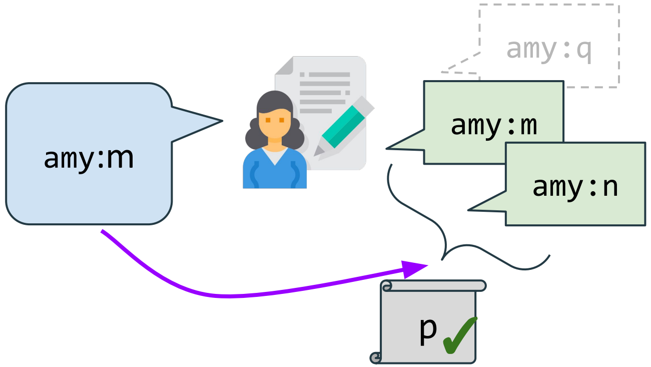
Concepts: 4/7



- The set of actions grows at runtime.
- The author of each action is evident: the author of the statement it enacts.
- Each action is justified by a message set. Its extracted policy must be valid. ⟶ Valid policies determine justified actions.

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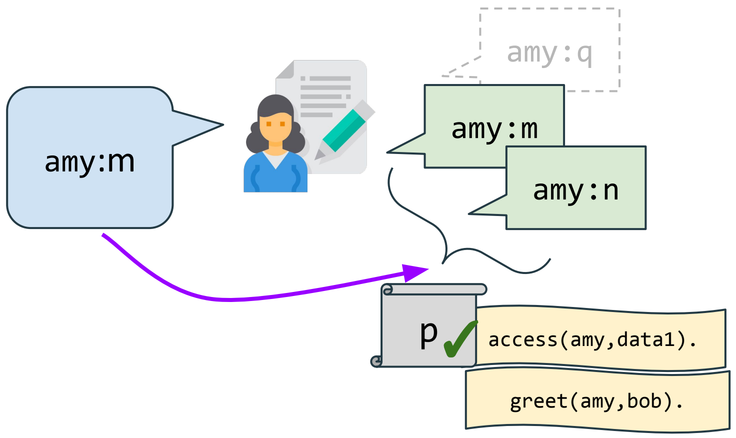
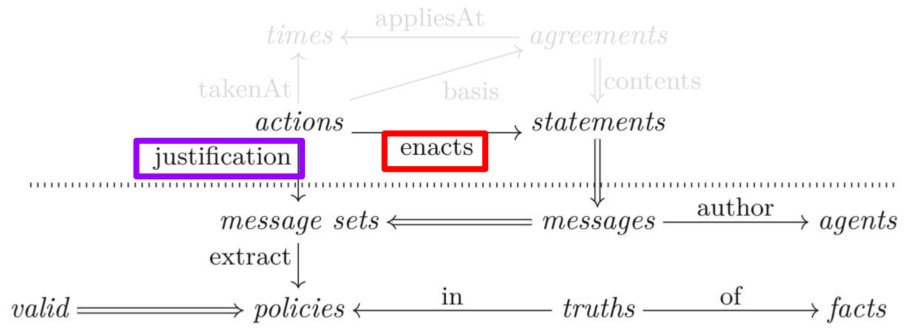
Concepts: 5/7



- Each policy is a model of the domain (e.g., policies = deterministic logic programs).
- → All agents agree on a given action's
  - effects
  - justifiaction and validity



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A Usage Example

Model of domain relations in extract($\{s_1\}$)

A priori agreement to empower the admin.

```
% Statement 's1' by 'consortium' (contents of agreement at time 1)
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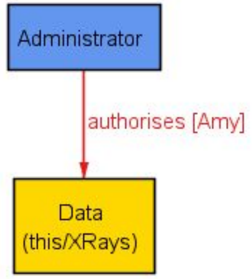

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Administrator authorises a particular data-access.

```
% Statement 's2' by 'administrator'
ctl-authorises(administrator, amy, x-rays).
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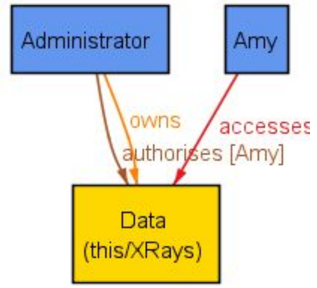
A Usage Example

Model of domain relations in extract($\{s_1, s_2, s_3\}$)



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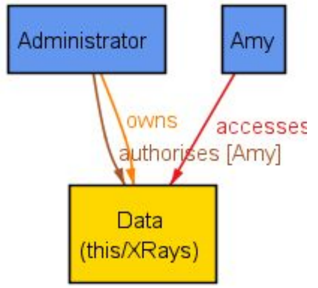
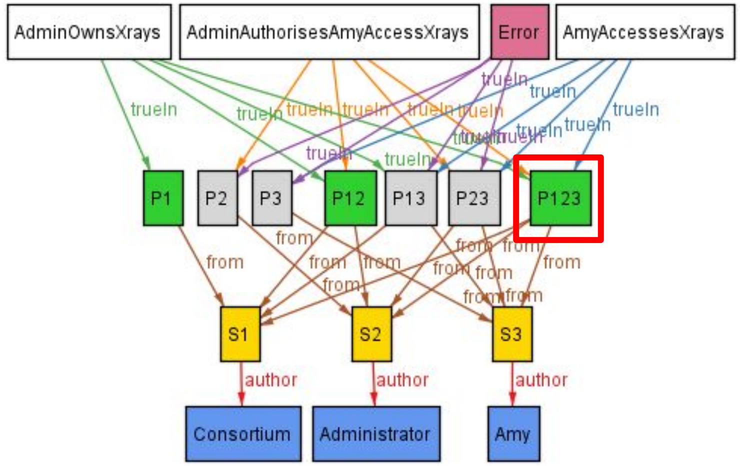


Model of framework-level relations



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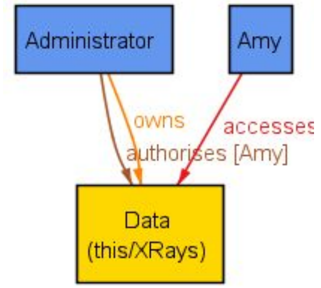

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← Amy can enact this, as justified by $\{s_1,s_2,s_3\}$

All observers agree:

- That it is permitted
- On the effects

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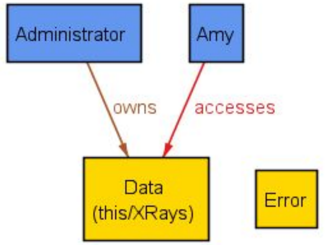

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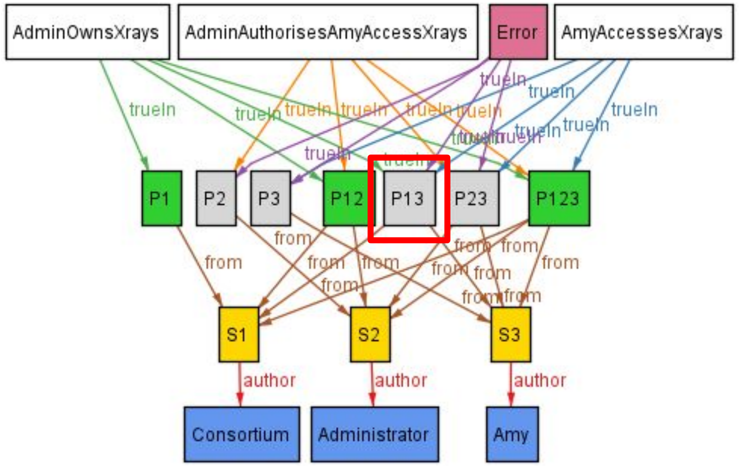

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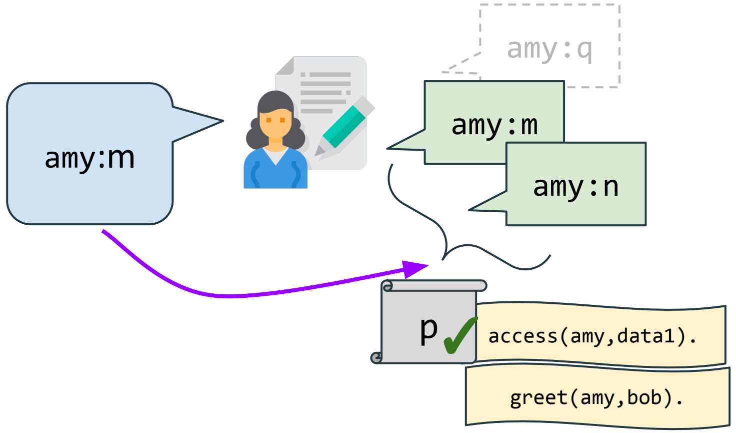
← Amy can enact this as justified by $\{s_3\}$?

Concepts: 5/7



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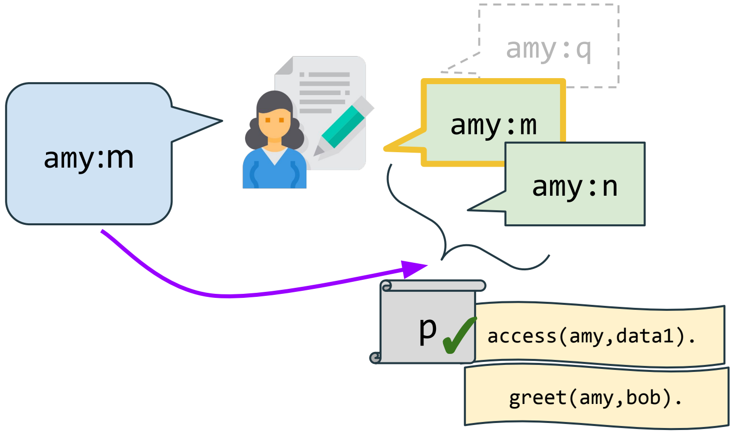
Concepts: 6/7



- Agreements are special statements.
  That a statement is an agreement is evident.
- Each action is based on some agreement.
  The agreement must be in the justification.
- → Agreements determine justifications

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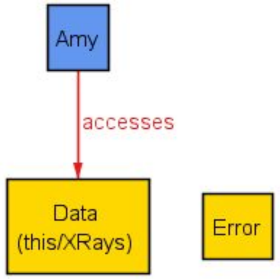

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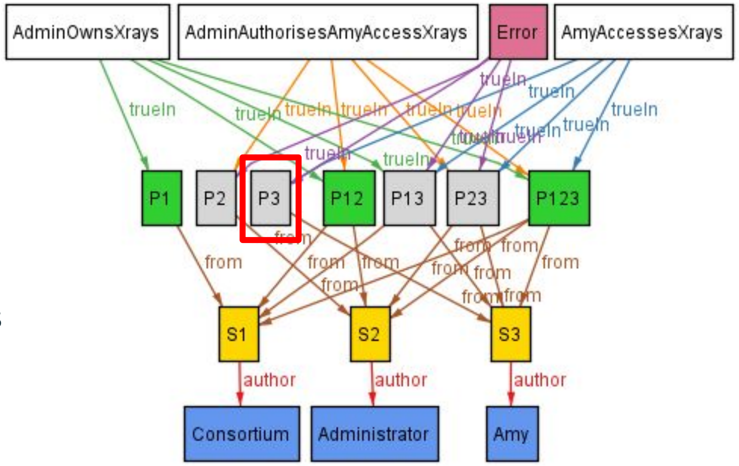

Amy accesses X-rays

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% Statement 's3' authored by 'amy'
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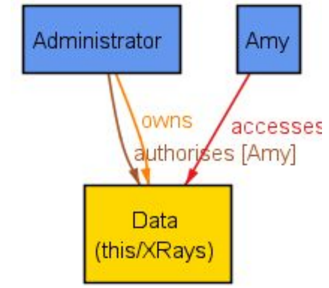
← Amy can enact this but $\{s_3\}$ is invalid

A Usage Example

Model of domain relations in extract($\{s_1,s_2,s_3\}$)



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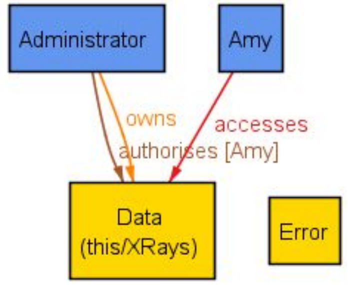

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Amy accesses X-rays

```
% Statement 's3' authored by 'amy'
ctl-accesses(amy, x-rays).
```

A Usage Example

The consortium “takes back” the agreement?

```
% Statement 's1' by 'consortium' (contents of agreement at time 1)
owns(administrator, Data) :- ctl-accesses(Accessor, Data).
error :- ctl-accesses(Accessor, Data), owns(Owner, Data),
       not ctl-authorises(Owner, Accessor, Data).
```

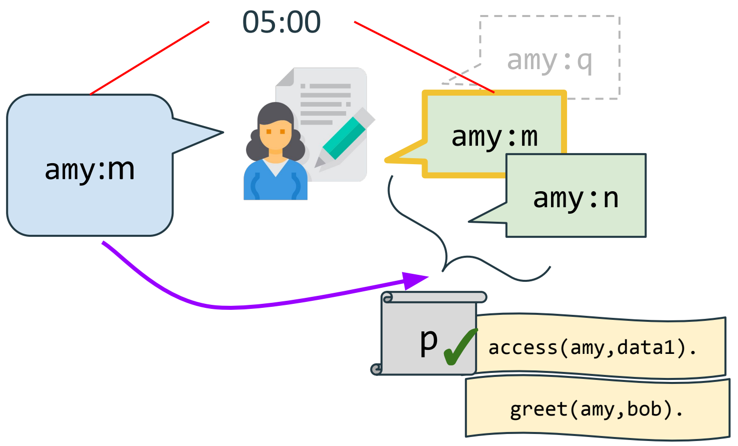
Administrator authorises a particular data-access.

```
% Statement 's2' by 'administrator'
ctl-authorises(administrator, amy, x-rays).
```

Amy accesses X-rays

```
% Statement 's3' authored by 'amy'
ctl-accesses(amy, x-rays).
```

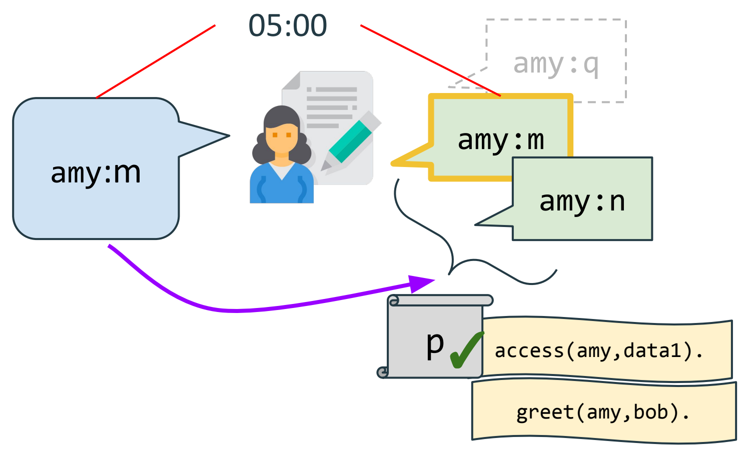
Concepts: 6/7



$$\begin{tikzcd}
 & \mathit{times} & \mathit{agreements} \arrow[l, "\text{appliesAt}"'] \arrow[d, Rightarrow, "\text{contents}"] & \\
 & \mathit{actions} \arrow[u, "\text{takenAt}"] \arrow[ur, "\text{basis}"'] \arrow[r, "\text{enacts}"'] \arrow[d, "\text{justification}"'] & \mathit{statements} \arrow[d, Rightarrow] & \\
 & \mathit{message\ sets} \arrow[d, "\text{extract}"'] & \mathit{messages} \arrow[l, Rightarrow] \arrow[r, "\text{author}"] & \mathit{agents} \\
\mathit{valid} \arrow[r, Rightarrow] & \mathit{policies} & \mathit{truths} \arrow[l, "\text{in}"'] \arrow[r, "\text{of}"] & \mathit{facts}
\end{tikzcd}$$

Concepts: 7/7

- Actions and agreements are contextualised by time (instants). Each action must be contemporary with its basis agreement.
- → Changing the time effectively changes the agreements, i.e., this models mutability.



$$\begin{tikzcd}
 & \textit{times} & \textit{agreements} \arrow[l, "\text{appliesAt}"'] \arrow[d, Rightarrow, "\text{contents}"] & \\
 & \textit{actions} \arrow[u, "\text{takenAt}"] \arrow[ur, "\text{basis}"'] \arrow[r, "\text{enacts}"'] \arrow[d, "\text{justification}"'] & \textit{statements} \arrow[d, Rightarrow] & \\
 & \textit{message sets} \arrow[d, "\text{extract}"'] & \textit{messages} \arrow[l, Rightarrow] \arrow[r, "\text{author}"] & \textit{agents} \\
\textit{valid} \arrow[r, Rightarrow] & \textit{policies} & \textit{truths} \arrow[l, "\text{in}"'] \arrow[r, "\text{of}"] & \textit{facts}
\end{tikzcd}$$

A Usage Example

The consortium “takes back” the agreement?

```
% Statement 's11' by 'consortium' (contents of agreement at time 1)
~~owns(administrator, Data) :- ctl-accesses(Accessor, Data).~~
error :- ctl-accesses(Accessor, Data), owns(Owner, Data),
      not ctl-authorises(Owner, Accessor, Data).
```

Administrator authorises a particular data-access.

```
% Statement 's2' by 'administrator'
ctl-authorises(administrator, amy, x-rays).
```

Amy accesses X-rays

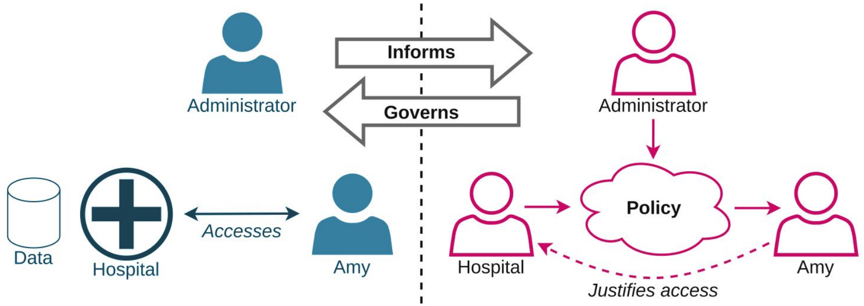
```
% Statement 's3' authored by 'amy'
ctl-accesses(amy, x-rays).
```

Characteristics

amy:m ✓
amy:m
amy:n

In systems implementing the framework…

- Agents can make statements and take actions autonomously, lossily, asynchronously.
- It suffices for the relevant policies to reach the relevant actors.
- Only agreements must be synchronised.
- All agents (e.g., an auditor) can decide whether a given action is permitted.



Looking Forward

Work continues to develop and use the framework:

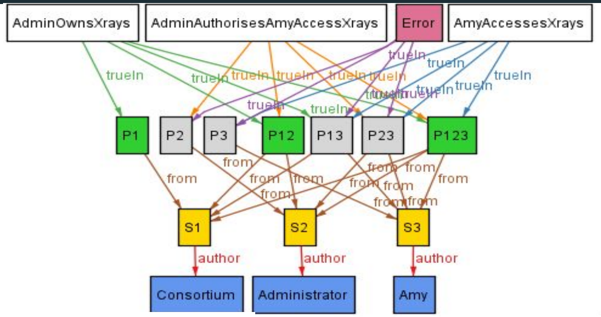
1. We **develop policy languages** for this
   a. We adapt existing languages (see PLNL!)

2. We experiment with **implementations**.

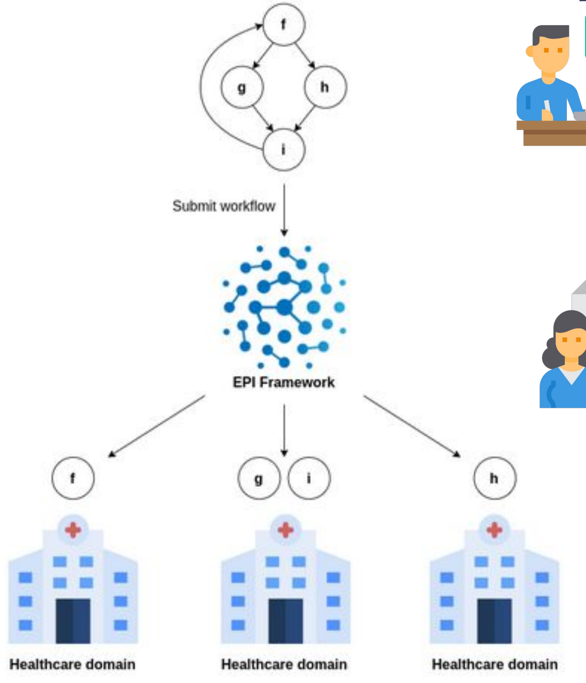
3. We **automate agent work**:
   a. Policy analysis and search via ASP

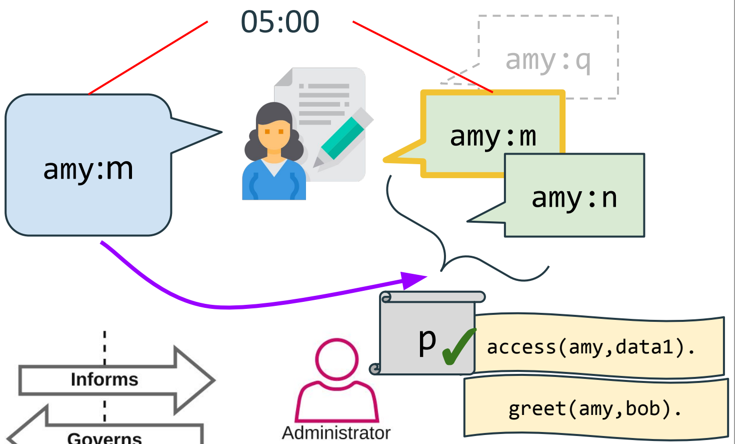
4. Extend framework to explicitly **treat privacy**.

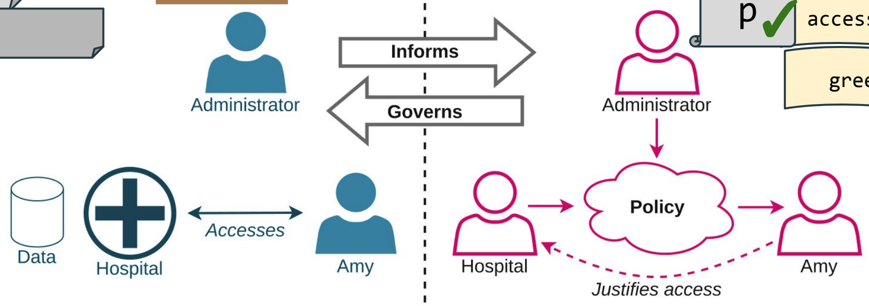
End.



$$\begin{tikzcd}
 & times & agreements \arrow[l, "appliesAt"'] \arrow[d, Rightarrow, "contents"] & \\
 & actions \arrow[u, "takenAt"] \arrow[ur, "basis"] \arrow[r, "enacts"'] \arrow[d, "justification"'] & statements \arrow[d, Rightarrow] & \\
 & message\ sets \arrow[d, "extract"'] & messages \arrow[l, Rightarrow] \arrow[r, "author"] & agents \\
valid \arrow[r, Rightarrow] & policies & truths \arrow[l, "in"'] \arrow[r, "of"] & facts
\end{tikzcd}$$







Graveyard

A Usage Example

A priori agreement to empower the admin.

```
% Statement 's1' by 'consortium' (contents of agreement at time 1)
owns(administrator, Data) :- ctl-accesses(Accessor, Data).
error :- ctl-accesses(Accessor, Data), owns(Owner, Data),
      not ctl-authorises(Owner, Accessor, Data).
```

Administrator authorises a particular data-access.

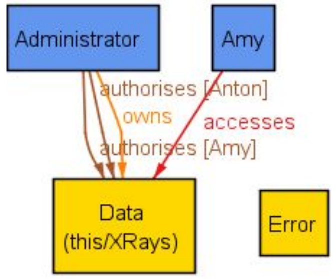
```
% Statement 's2' by 'administrator'
ctl-authorises(administrator, amy, x-rays).
```

Anton "the antagonist" considers misbehaving.

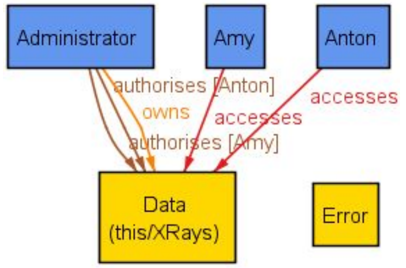
```
% Statement 's4' authored by 'anton'
ctl-authorises(administrator, anton, x-rays).
```

```
% Statement 's5' authored by 'anton'
owns(anton, x-rays).
```

Model of domain relations in extract({s_1,s_2,s_4})



Model of domain relations in extract({s_1,s_2,s_4,s_5})



A Usage Example

Model of domain relations in extract($s_{6\text{-}8}$)

A priori agreement to empower the admin.

```
% Statement 's6' authored by 'administrator'
ctl-authorises(administrator, bob, x-rays)
        :- ctl-authorises(h1, bob, x-rays),
           ctl-authorises(h2, bob, x-rays).
```

Hospitals h_1 and h_2 condition their authorisations.

```
% Statement 's7' authored by 'h1'
ctl-authorises(h1, Accessor, x-rays)
:- ctl-authorises(h2, Accessor, x-rays).
```

```
% Statement 's8' authored by 'h2'
ctl-authorises(h2, Accessor, x-rays)
  :- ctl-accesses(Accessor, x-rays),
 not ctl-accesses(anton   , x-rays).
```

A Usage Example

Model of domain relations in extract($s_{6\text{-}8}$)

A priori agreement to empower the admin.

```
% Statement 's6' authored by 'administrator'
ctl-authorises(administrator, bob, x-rays)
        :- ctl-authorises(h1, bob, x-rays),
           ctl-authorises(h2, bob, x-rays).
```

Hospitals h_1 and h_2 condition their authorisations.

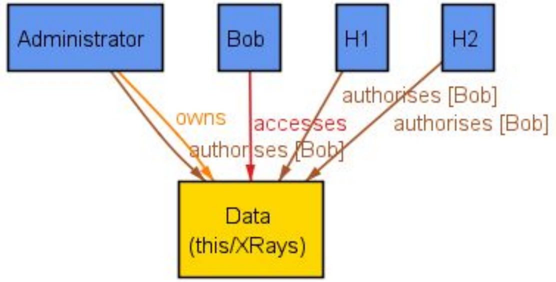
```
% Statement 's7' authored by 'h1'
ctl-authorises(h1, Accessor, x-rays)
:- ctl-authorises(h2, Accessor, x-rays).
```

```
% Statement 's8' authored by 'h2'
ctl-authorises(h2, Accessor, x-rays)
  :- ctl-accesses(Accessor, x-rays),
 not ctl-accesses(anton    , x-rays).
```

Bob accesses data (justifiably!)

```
% Statement 's9' authored by 'bob'
ctl-accesses(bob, x-rays).
```

Model of domain relations in extract($\{s_6,s_7,s_8,s_9\}$)



A Usage Example

Model of domain relations in extract(s_{6-8})

A priori agreement to empower the admin.

```
% Statement 's6' authored by 'administrator'
ctl-authorises(administrator, bob, x-rays)
        :- ctl-authorises(h1, bob, x-rays),
           ctl-authorises(h2, bob, x-rays).
```

Hospitals h_1 and h_2 condition their authorisations.

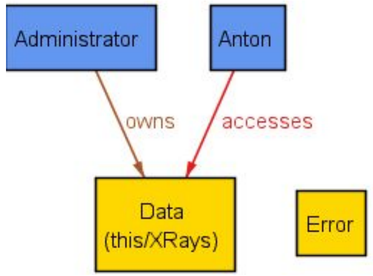
```
% Statement 's7' authored by 'h1'
ctl-authorises(h1, Accessor, x-rays)
:- ctl-authorises(h2, Accessor, x-rays).
```

```
% Statement 's8' authored by 'h2'
ctl-authorises(h2, Accessor, x-rays)
  :- ctl-accesses(Accessor, x-rays),
 not ctl-accesses(anton    , x-rays).
```

Anton accesses data (unjustifiably!)

```
% Statement 's10' authored by 'anton'
ctl-accesses(anton, x-rays).
```

Model of domain relations in extract($\{s_6, s_7, s_8, s_{10}\}$)


Administrator
Anton
owns
accesses
Data (this/XRays)
Error