eFLINT - A DSL for Testing Normative Specifications

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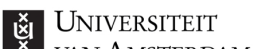
Centrum Wiskunde & Informatica

22 November, 2019

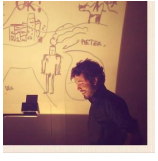


People

UvA and more

Robert van Doesburg

Tom van Engers



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CWI

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People

Policy-CAD

UvA and more

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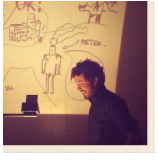

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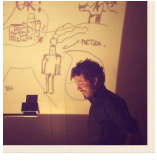

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Norms - Philosophy/Sociology

Normative sentences are "ought-to" types of statements

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Examples: legal norms - social norms

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Examples: legal norms - social norms

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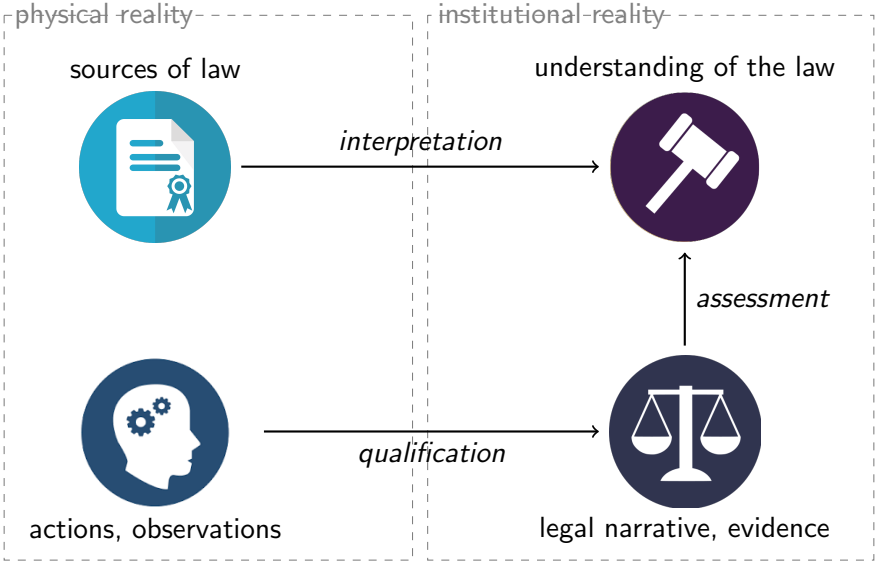
A player cannot score from an offside position

Deontic	**Potestative**
duties, obligations	powers, actions
permissions	liabilities

Analyzing legal cases



Interpreting normative sources

What does the result of interpretation look like?

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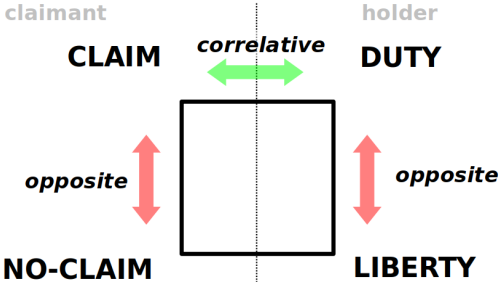
How do we write down an interpretation formally?

Hohfeld's fundamental legal conceptions



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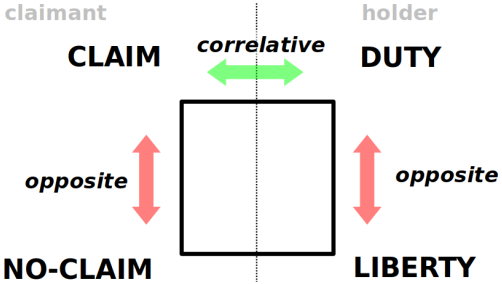

fundamental relation: **duty-claim**
between *duty holder* and *claimant*

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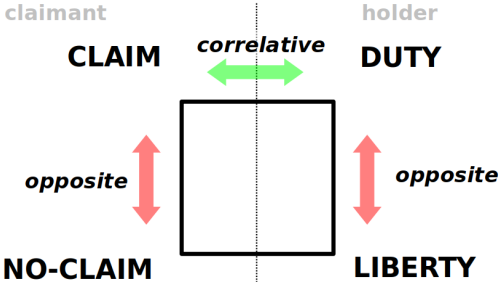

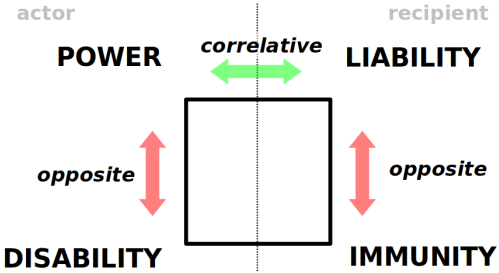

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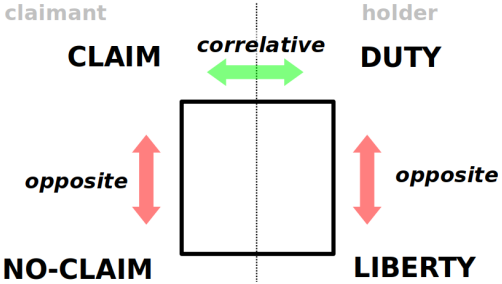

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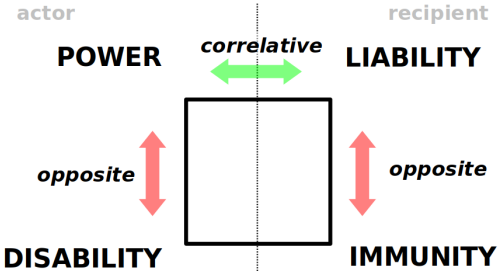

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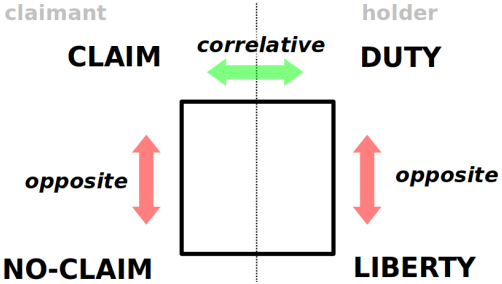

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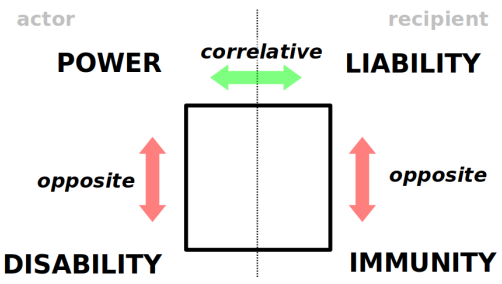

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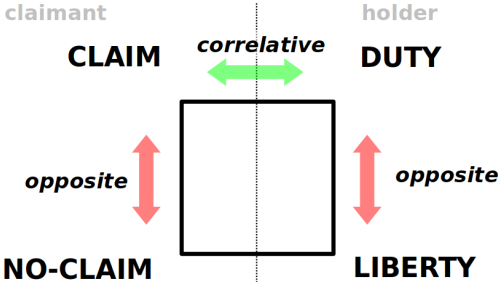

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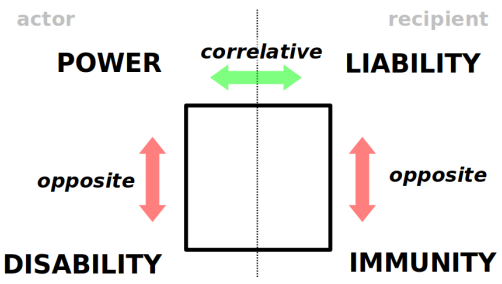

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How do we write down an interpretation formally?

Formal Language for the Interpretation of Norms (FLINT)

Robert van Doesburg / Tijs van der Storm / eFLINT

Commonalities

- Judgements characterize the relevant sub-set of the world
  - certain facts are postulated (to hold true or false)
  - other facts are derived (from other judgements)
- Transition rules determine the availability of actions and their effects

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Challenges

- Language design: appeal, scope, fit-for-purpose ...
- Policy design: consistency, composition, qualification ...
- Policy analysis: exploration, testing, verification, reasoning, planning ...
- System compliance: testing, verification, “by construction” ...

Language design - overview

1. World: values, types, expressions
2. Norms: duties, acts, transitions
3. Pragmatics: refinement, scripts, testing

Facts

Fact-type declarations associate a type with a fact identifier:

```
1 Fact citizen
2 Fact candidate       Identified by Atom
3 Fact administrator   Identified by Atom
4 Fact voter           Identified by citizen
5 Fact winner          Identified by candidate
6 Fact vote            Identified by (voter * candidate)
```

Type expressions

Types are essentially record-types:

$$
\begin{array}{lllll}
x \in & \texttt{vars} & ::= & \ldots \\
s \in & \texttt{atoms} & ::= & \ldots \\
i \in & \mathbb{Z} & ::= & \ldots \\
\tau \in & \texttt{types} & ::= & \texttt{atoms} \\
 & & | & \mathit{atom\_set}(s_1, \ldots, s_n) \\
 & & | & \mathbb{Z} \\
 & & | & \mathit{int\_set}(i_1, \ldots, i_n) \\
 & & | & \mathit{fields}(x_1, \ldots, x_n)
\end{array}
$$

- Field names are variables (possibly decorated fact identifiers)

Instances

```
1  Alice
2  7
3
4  Alice:citizen
5  Chloe:candidate
6  Admin:administrator
7
8  (Alice:citizen):voter
9
10 ((Alice:citizen):voter, Chloe:candidate):vote
```

example instances

Instances

```
1  Alice
2  7
3
4  Alice:citizen
5  Chloe:candidate
6  Admin:administrator
7
8  (Alice:citizen):voter
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10 ((Alice:citizen):voter, Chloe:candidate):vote
```

example instances

The state of the world at any particular moment is a set of instances σ, containing those instances that *hold true* at that moment

Expressions

- Expressions evaluate to atoms, integers, Booleans or instances of fact-types

```
1  citizen
2  citizen(Alice)
3
4  voter(citizen(Alice))
5  voter(Alice)
6  voter(citizen = citizen(Alice))
7
8  vote(voter(Alice), Chloe)
9  vote(voter = voter(Alice), candidate = Chloe)
10 vote(candidate = Chloe, voter = voter(Alice))
11
12 vote(voter = voter(Alice))
13 vote(candidate = candidate, voter = voter(Alice))
14 vote()
```

variables and constructors

Operators

```
1  Holds(voter(Alice))
2
3  vote[voter]
4  vote[candidate]
5
6  vote[candidate] When Holds(vote)
7  vote[candidate] When vote
```

operators

Quantifiers and aggregators

Quantifiers bind variables to all instances of the variable's type:

```
1 (Exists candidate : vote(voter(Alice), candidate))
2
3 (Forall citizen : vote(voter(citizen), Chloe))
```

Foreach can only be used in combination with an *aggregator*:

```
1 Count(Foreach vote : vote When Holds(vote) && vote[candidate] = candidate)
```

Derived facts

Derivation expression as a predicate (type-components are bound):

```
1 Fact has voted Identified by voter
2   Holds when (Exists candidate : vote(voter,candidate))
```

```
1 Predicate vote concluded When (Exists candidate : winner(candidate))
2 Predicate voters done  When (Forall citizen : !voter() || has voted(voter()))
```

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Derivation expression computes the set of instances that hold true:

```
1 Fact number of votes Identified by Int
2   Derived from Count(Foreach vote : vote When Holds(vote))
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```

- Derived facts cannot be postulated

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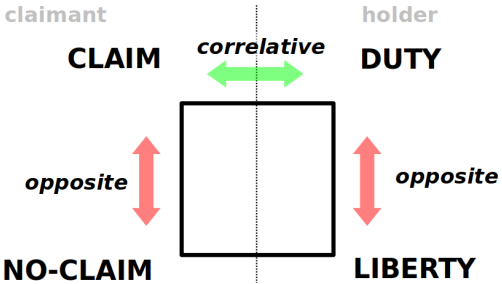
Recall Hohfeld's conceptions



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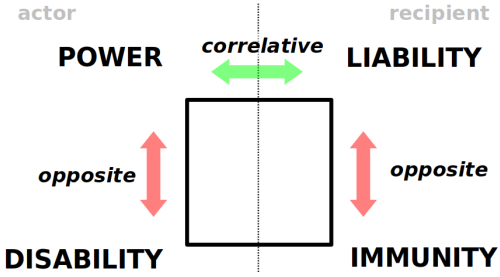

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How do we write down an interpretation formally?

Duties

A duty indicate that its holder ought to perform some action:

```
1 Duty cast vote duty Holder voter Claimant administrator
```

- A duty-type declaration is a fact-type declaration with a record-type

Acts

Actions modify the world by adding or removing instances from σ:

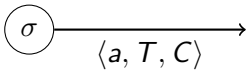
```
1  Act cast vote
2    Actor voter
3    Recipient administrator
4    Related to candidate
5    Conditioned by voter && !has voted()
6    Creates vote()
7    Terminates cast vote duty()
```

- An act-type declaration is a fact-type declaration with a record-type

Transitions

A transition is a state σ, an instance a of an act, and the sets T and C of instances terminated and created by the act, if and only if:

1. a holds true in σ
2. the pre-condition of a holds in σ
3. T is the result of evaluating the terminating post-conditions of a in σ
4. C is the result of evaluating the creating post-conditions of a in σ

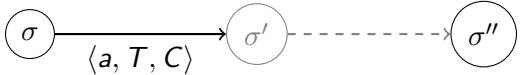


More acts

Derived facts may have to be recomputed after an action is performed:

```
1 Act cast vote
2   Actor voter
3   Recipient administrator
4   Related to candidate
5   Conditioned by voter && !has voted()
6   Creates vote()
7   Terminates cast vote duty()
```

- σ' may be incomplete and inconsistent w.r.t. derivation expressions



Completing the example (1)

```
1  Act enable vote
2    Actor administrator
3    Recipient citizen
4    Conditioned by !voter() && !vote concluded()
5    Creates voter(),
6           cast vote duty(voter = voter()),
7           (Foreach candidate : cast vote(voter = voter()))
```

Completing the example (2)

Placeholders can be introduced for types:

```
Placeholder other candidate For candidate
```

```
Act declare winner
  Actor administrator
  Recipient candidate
  Conditioned by
      !vote concluded()
   && voters done()
   && (Forall other candidate :
         Count(Foreach vote : vote[voter]
                 When vote && vote[candidate] == other candidate) <
         Count(Foreach vote : vote[voter]
                 When vote && vote[candidate] == candidate)
       When other candidate != candidate)
  Creates winner(candidate)
```

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Refinement

A refinement of a policy description replaces all simple, infinite types with finite types:

```
1 Fact citizen       Identified by [John, Frank, Peter, Chloe, Hannah]
2 Fact candidate     Identified by [Mary, David]
3 Fact administrator Identified by Admin
```

and also identifies an initial state (implicit Foreach):

```
1 administrator.
2 citizen.
3 candidate.
4 declare winner(Admin, candidate).
5 enable vote(Admin, citizen).
```

- A refinement enables exploring the reachable states manually

Scripts

- Scripts are basic programs for stepping through reachability graphs

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Action call !<EXPR>. evaluates to an enabled act and executes it (or fails)

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Action call !<EXPR>. evaluates to an enabled act and executes it (or fails)

Query ?<EXPR>. fails if expression does not evaluate to True in the current state

Scripts - positive test

```
1 !enable vote(citizen = John).
2 !enable vote(citizen = Frank).
3 !enable vote(citizen = Peter).
4 !cast vote(voter = voter(John), candidate = Mary).
5 !cast vote(voter = voter(Frank), candidate = Mary).
6 !cast vote(voter = voter(Peter), candidate = David).
7 !declare winner().
8 ?winner(Mary).
9 ?(Forall candidate : !winner() When candidate != Mary).
```

Scripts - negative test

```
1 !enable vote(citizen = John).
2 !enable vote(citizen = Frank).
3 !enable vote(citizen = Peter).
4 !cast vote(voter = voter(Frank), candidate = Mary).
5 !cast vote(voter = voter(Peter), candidate = David).
6 !enable vote(citizen = Hannah).
7 !cast vote(voter = voter(Hannah), candidate = David).
8 !declare winner().
```

Scripts - negative test 2

```
1 !enable vote(citizen = John).
2 !enable vote(citizen = Frank).
3 !enable vote(citizen = Peter).
4 !cast vote(voter = voter(Frank), candidate = Mary).
5 !cast vote(voter = voter(Peter), candidate = David).
6 !enable vote(citizen = Hannah).
7 !cast vote(voter = voter(Hannah), candidate = David).
8 !cast vote(voter = voter(John), candidate = Mary).
9 !declare winner().
```

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Reflection

Curb your enthusiasm Thomas...

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- Policy analysis: exploration, testing, verification, reasoning, planning ...
- System compliance: testing, verification, "by construction" ...

```
public void register_voter(String name) {
  registered_voters.add(name);
  ScriptGen.add_actor(name, "citizen"); // qualification
  ScriptGen.enable_vote(name);
}

public void register_candidate(String name) {
  vote_count.put(name,0);
  ScriptGen.add_actor(name, "candidate"); // qualification
}

public void vote(String voter, String candidate) {
  vote_count.put(candidate, vote_count.getOrDefault(candidate,0) + 1);
  ScriptGen.cast_vote(voter, candidate); // qualification
}

public String find_winner() { // returns null if there is no winner
  String winner = null;
  int winning_votes = 0;
  for (Entry<String,Integer> entry : vote_count.entrySet()) {
    if(entry.getValue() > winning_votes) {
      winner = entry.getKey();
      winning_votes = entry.getValue();
    }
  }
  if (winner != null) { // qualification
    ScriptGen.declare_winner(winner);
  }
  return winner;
}
```

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