Towards a DSL for formalising laws and regulations

intermediate findings and results

L. Thomas van Binsbergen

Informatics Institute, University of Amsterdam
ltvanbinsbergen@acm.org

September 9, 2021
Strumenta, Virtual Meetup

UNIVERSITY OF AMSTERDAM

Overview

1. Regulated systems
   Relating normative and computational concepts
2. The eFLINT language
   eFLINT 1.0
   eFLINT 2.0
   Goals for eFLINT 3.0
3. Reflections

Section 1

Regulated systems

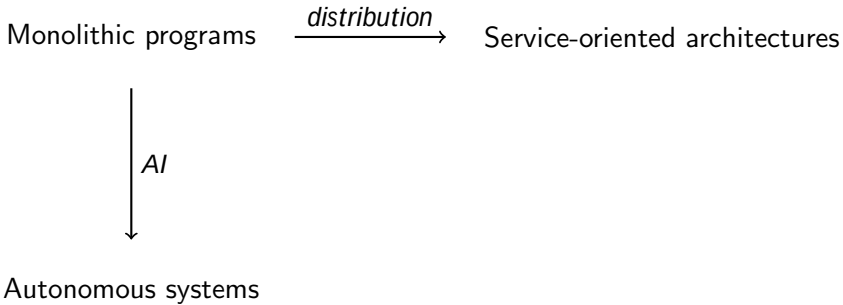
Towards regulated systems

Monolithic programs

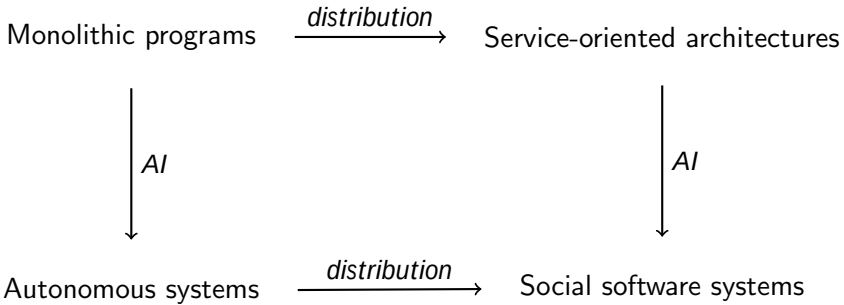
Towards regulated systems

Monolithic programs $\xrightarrow{\textit{distribution}}$ Service-oriented architectures

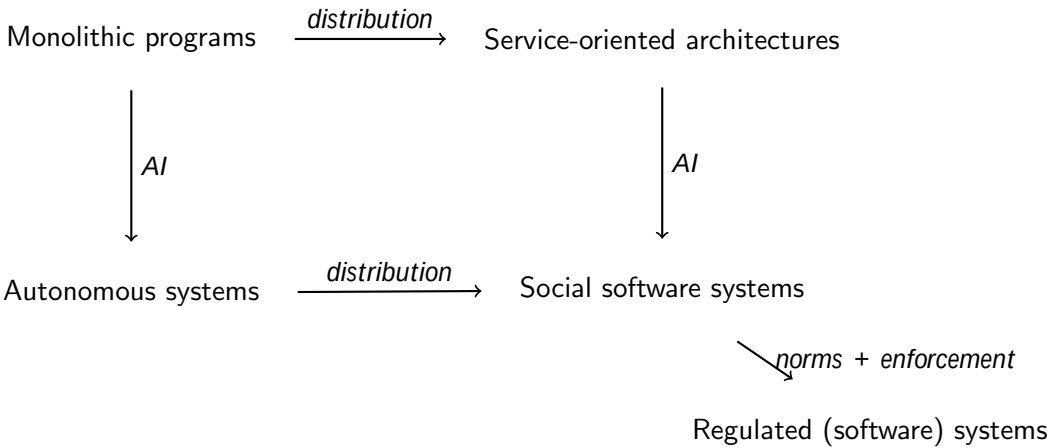
Towards regulated systems



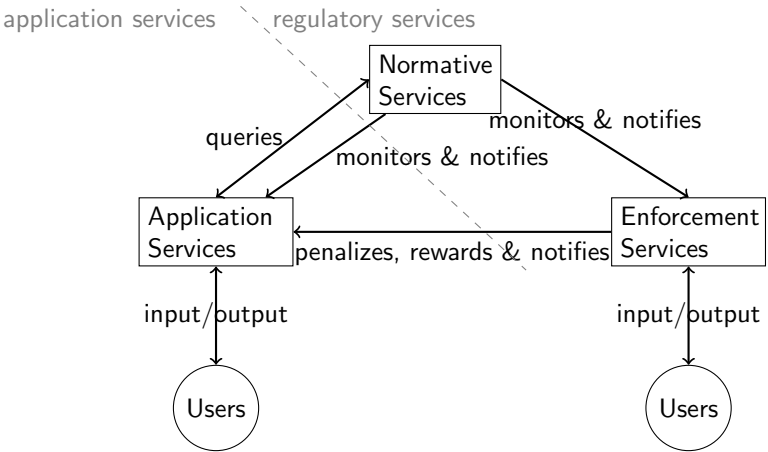
Towards regulated systems



Towards regulated systems



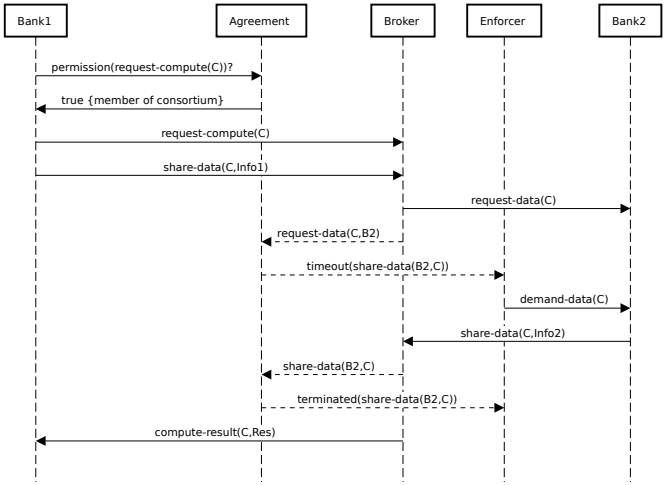
Regulated system = application services + regulatory services



Dynamic enforcement examples – sharing agreement

(Article 1) A member of the consortium has the right to request a risk assessment computation from the broker for any (potential) client

(Article 2) The data broker has the power to oblige members of the consortium to share information about any client the member does business with



Our approach to model-driven experimentation

eFLINT – formalization of norms from a variety of sources
declarative reasoning about facts, actions and duties
reactive component for integration in software systems
including actor-based implementation

AgentScriptCC – specification of services as agents
reactive BDI agents,
compiled to actor-based implementation

Actor-oriented programming in the Akka framework:
`https://akka.io/`
actor systems modelling social software systems

eFLINT: A Domain-Specific Language for Executable Norm Specifications

L. Thomas van Binsbergen
Centrum Wiskunde & Informatica
Amsterdam, The Netherlands
lvanbinsbergen@acm.org

Lu-Chi Liu
University of Amsterdam
Amsterdam, The Netherlands
l.liu@uva.nl

Robert van Doesburg
Leibniz Institute, University of Amsterdam / TNO
Amsterdam, The Netherlands
robertsandoesburg@uva.nl

Tom van Engers
Leibniz Institute, University of Amsterdam / TNO
Amsterdam, The Netherlands
vanengers@uva.nl

published @ SPLASH 2020

Run, Agent, Run

Architecture and Benchmarking of Actor-based Agents

Mostafa Mohajeri Parizi
m.mohajeriparizi@uva.nl
Informatics Institute, University of Amsterdam
Amsterdam, the Netherlands

Giovanni Sileno
g.sileno@uva.nl
Informatics Institute, University of Amsterdam
Amsterdam, the Netherlands

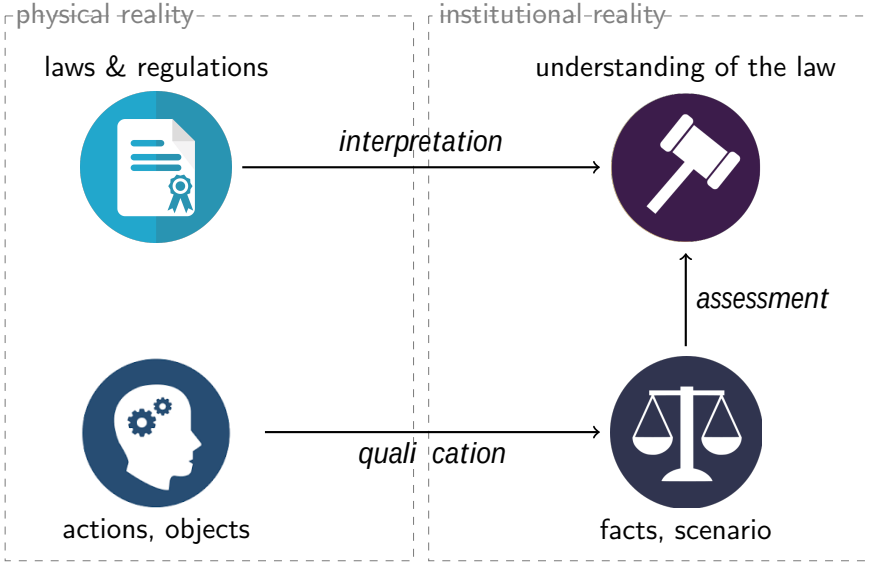
Tom van Engers
vanengers@uva.nl
Informatics Institute, University of Amsterdam
Amsterdam, the Netherlands

Sander Klous
s.klous@uva.nl
Informatics Institute, University of Amsterdam
Amsterdam, the Netherlands

published @ SPLASH 2020

Subsection 1

Relating normative and computational concepts



\If the facts are against you, argue the law. If the law is against you, argue the facts. If the law and the facts are against you, pound the table ..." -Carl Sandburg

Foundational, normative & computational concepts

computational

state

$parent(A; B) = true$

...

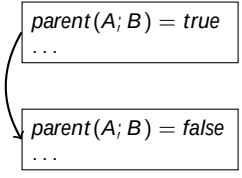
Foundational, normative & computational concepts

computational

state

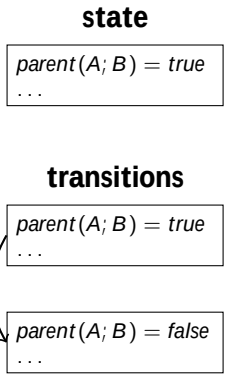
$parent(A; B) = true$
...

transitions



Foundational, normative & computational concepts

computational



Violations of state and transition

Foundational, normative & computational concepts

deontic

computational

prohibitions

permissions

obligations

state

$parent(A; B) = true$
...

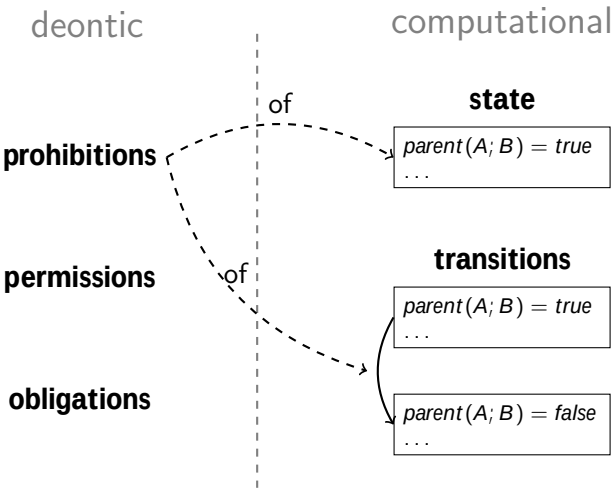
transitions

$parent(A; B) = true$
...

$parent(A; B) = false$
...

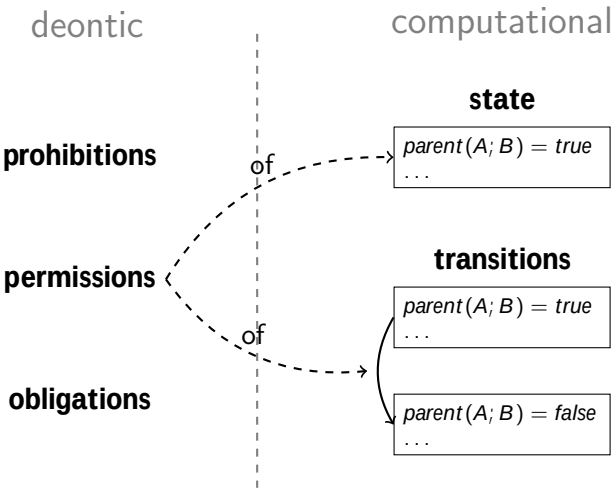
Violations of state and transition

Foundational, normative & computational concepts



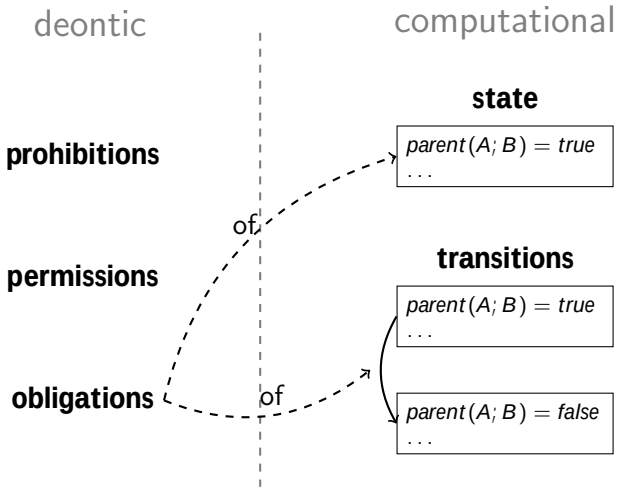
Violations of state and transition

Foundational, normative & computational concepts



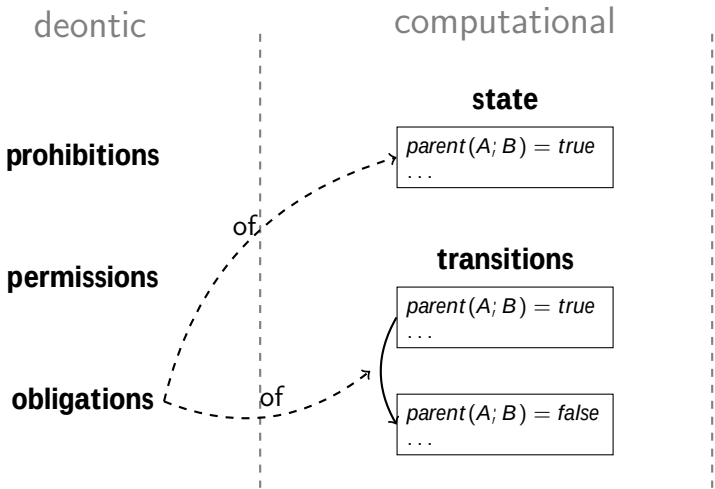
Violations of state and transition

Foundational, normative & computational concepts



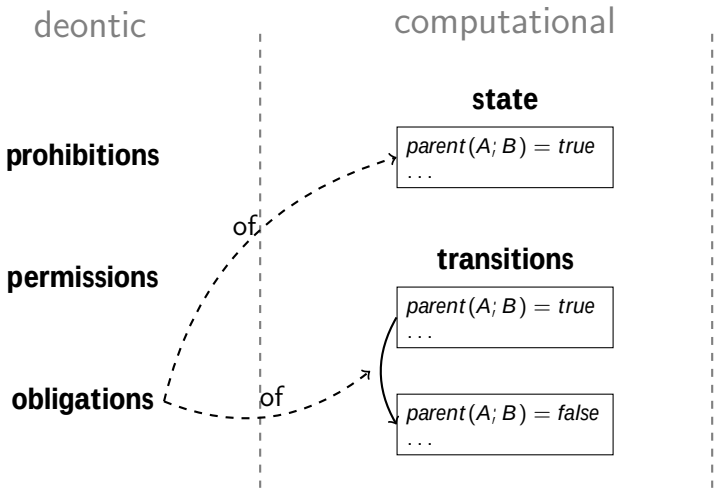
Violations of state and transition

Foundational, normative & computational concepts

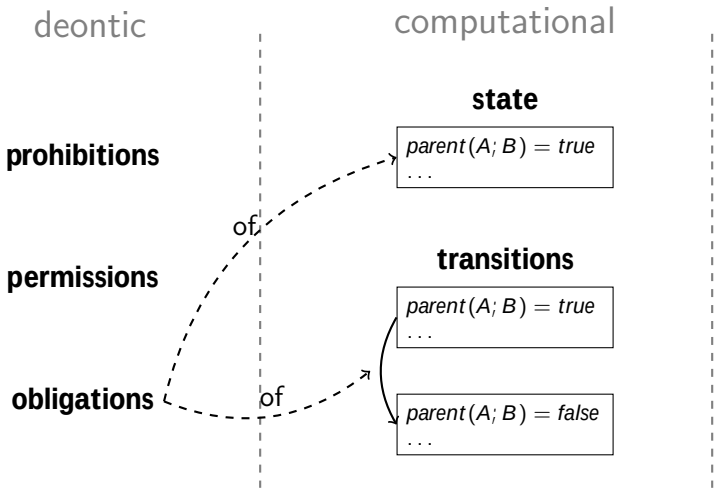


Violations of state and transition

Foundational, normative & computational concepts



Foundational, normative & computational concepts



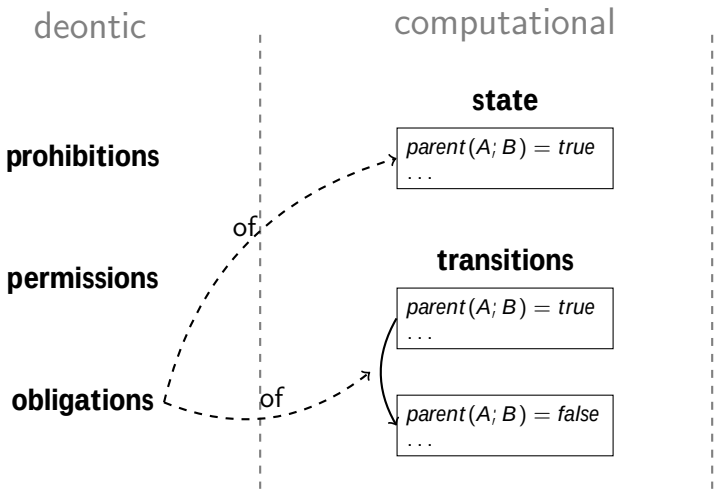
powers

Powers have (normative) consequences

Deontic and potestative terms are first-class

Powers modify truth-assignments to variables

Foundational, normative & computational concepts



powers

Powers have (normative) consequences

Deontic and potestative terms are first-class

Powers modify truth-assignments to variables

Explicit permissions cause conflicts

Normative relations between actors

A deontic value is associated with several actors:

- The **holder** of the prohibition, obligation or prohibition
- Zero or more **claimants** to the prohibition or obligation
- The actor who **assigned** the prohibition, obligation or permission

A potestative value is associated with several actors

- The **performing** actor
- One or more **recipients** being affected by the power
- The actor who **assigned** the power

Regulated systems – points to address

Formalization of applicable norms: reusable, modular and dynamically updateable

Different methods of embedding and enforcing norms:

- Static ex-ante: verify and apply norms during software production
  e.g. correct-by-construction arguments, model checking
- Dynamic ex-ante: apply rules at run-time, guaranteeing compliance
  enables decisions (behavioral, normative) that depend on input
- Embedded ex-post enforcement: specified responses to violations
  enables (regulated) non-compliant behavior, e.g. based on risk assessment by agent
- External ex-post enforcement: external responses to violations
  e.g. auditing, conformance checking
  enables (human-)intervention in running system

Production of diagnostic reports and/or audit trails to enable evaluation and reflection

Regulated *systems* – points to address

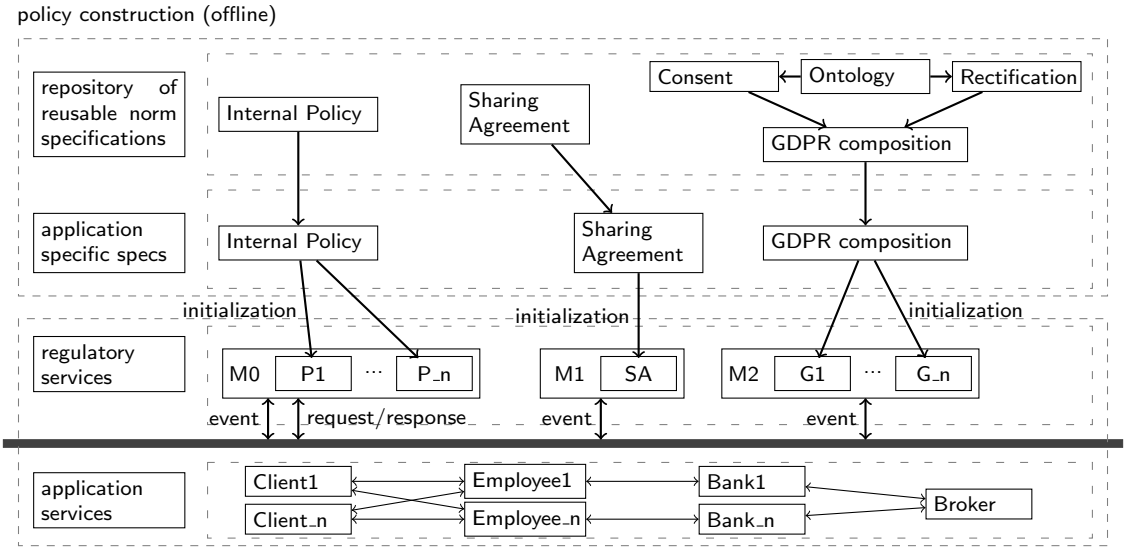
Derivation of regulatory services from formalization of norms

Interfacing between application and regulatory services:

- Monitoring (communicated and silent) behavior of services
  di culties: fallible and subject to manipulation
- Regulatory services responding to queries about normative positions
  e.g. do I have permission to...? or the obligation to... ?
- Application services verifying facts on behalf of regulatory services
  e.g. verifying credentials or certi cates
- Regulatory services communicating changes in normative positions
  e.g. gaining/losing powers, holding/satisfying obligations, violations

Challenges: different interpretations of norms and different qualifications of situations

Regulated systems for Know Your Customer case study



Section 2

The eFLINT language

Subsection 1

eFLINT 1.0

Example – knowledge representation

(Toy Article 1) a natural person is a legal parent of another natural person if:

they are a natural parent, or

they are an adoptive parent

```
Fact person Identified by String
Placeholder parent    For person
Placeholder child     For person

Fact natural-parent   Identified by parent * child
Fact adoptive-parent  Identified by parent * child

Fact legal-parent     Identified by parent * child
  Holds when adoptive-parent(parent,child)
          || natural-parent(parent,child)
```

Example – powers and duties

(Toy Article 2) a child has the power to ask a legal parent for help with their homework, resulting in a duty for the parent to help.

```
Act ask-for-help
  Actor       child
  Recipient   parent
  Creates     help-with-homework(parent,child)
  Holds when  legal-parent(parent,child)

Duty help-with-homework
  Holder          parent
  Claimant        child
  Violated when   homework-due(child)

Fact homework-due Identified by child

Act help
  Actor       parent
  Recipient   child
  Terminates  help-with-homework(parent,child)
  Holds when  help-with-homework(parent,child)
```

Example – scenario

```
Fact person Identified by Alice, Bob, Chloe, David
```

Listing 1: Domain specification

```
+natural-parent(Alice, Bob).
+adoptive-parent(Chloe, David).
```

Listing 2: Initial state

```
ask-for-help(Bob, Alice).                    // Alice is Bob's legal parent
+homework-due(Bob).                          // homework deadline passed
?Violated(help-with-homework(Alice,Bob)).    // query duty violation
help(Alice,Bob).                             // duty terminated
```

Listing 3: Scenario

eFLINT online!

frames

```
Fact person Identified by String
Placeholder parent    For person
Placeholder child     For person

Fact natural-parent   Identified by parent * child
Fact adoptive-parent  Identified by parent * child
Fact legal-parent     Identified by parent * child
  Holds when adoptive-parent(parent,child)
          || natural-parent(parent,child)

Act ask-for-help
  Actor      child
  Recipient  parent
  Creates    help-with-homework(parent,child)
  Holds when legal-parent(parent,child)

Fact homework-due Identified by child

Duty help-with-homework
  Holder       parent
  Claimant     child
  Violated when homework-due(child)

Act help
  Actor      parent
  Recipient  child
  Terminates help-with-homework(parent,child)
  Holds when help-with-homework(parent,child)
```

domains

```
Fact person Identified by Alice, Bob, Chloe, David
```

initial state

```
natural-parent(Alice, Bob).
adoptive-parent(Chloe, David).
```

Examples

Knowledge representation: Vehicles | Departments | Count Votes | Cast Votes

GPCE2020 paper examples: Help with homework | GDPR

Various: Buyer/Seller (v1) | Buyer/Seller (v2) | Buyer/Seller (v3) | Permit Applications | Permit Applications (v2) | Multiple taxpayers | Voting

Load file: Browse... No file selected.

scenario

```
ask-for-help(Bob, Alice).
+homework-due(Bob).  // homework deadline passed
?Violated(help-with-homework(Alice,Bob)).
help(Alice,Bob).
```

Run Reset Save model name

response

```
* Duty violated at step 2
    ("Alice":person,"Bob":person):help-with-homework
```

output

Step 0: initial state

Step 1: ("Bob":person,"Alice":person):ask-for-help
  +("Alice":person,"Bob":person):help-with-homework

Step 2: ("Bob":person):homework-due
  +("Bob":person):homework-due

Step 3: query

Step 4: ("Alice":person,"Bob":person):help
  -("Alice":person,"Bob":person):help-with-homework

Subsection 2

eFLINT 2.0

Deriving REPLs and Notebooks for DSLs – ALE collaboration

From DSL Specification to Interactive Computer Programming Environment

Pierre Jeanjean
Inria, Univ Rennes, CNRS, IRISA
Rennes, France
pierre.jeanjean@inria.fr

Benoit Combemale
University of Toulouse
Toulouse, France
benoit.combemale@irit.fr

Olivier Barais
Univ Rennes, Inria, CNRS, IRISA
Rennes, France
olivier.barais@irisa.fr

Figure: Software Language Engineering 2019

Bacatá: Notebooks for DSLs, Almost for Free

Mauricio Verano Merino[a,d], Jurgen Vinju[a,b], and Tijs van der Storm[b,c]

a Eindhoven University of Technology, The Netherlands
b Centrum Wiskunde & Informatica, The Netherlands
c University of Groningen, The Netherlands
d Océ Technologies B.V., The Netherlands

Figure: Art, Science, and Engineering of Programming 2020

Deriving REPL/Notebook { commonalities

READ: Identify entry points, i.e. the alternatives in syntactic root
EVAL: Connect entry points with evaluation function in DSL interpreter
PRINT: Specify function to convert evaluation result to string
LOOP:

Deriving REPL/Notebook { commonalities

READ: Identify entry points, i.e. the alternatives in syntactic root
EVAL: Connect entry points with evaluation function in DSL interpreter
PRINT: Specify function to convert evaluation result to string
LOOP:

How does one execution a ect the next?

Idea..!

Distinguish between REPL language and base language (e.g. JShell vs Java)

Figure: Onward!2020

Observation..!

REPLs with incremental execution implement a language with the following property:

Observation..!

REPLs with incremental execution implement a language with the following property:

A sequential language is a language in which $p_1 \; p_2$ is a (syntactically) valid program if p_1 and p_2 are valid programs and if $p_1 \; p_2$ is equivalent to `doing' p_1 and then p_2

$$\llbracket p_1 \; p_2 \rrbracket = \llbracket p_2 \rrbracket \; \llbracket p_1 \rrbracket$$

Observation..!

REPLs with incremental execution implement a language with the following property:

A sequential language is a language in which $p_1 \; p_2$ is a (syntactically) valid program if p_1 and p_2 are valid programs and if $p_1 \; p_2$ is equivalent to `doing' p_1 and then p_2

$$\llbracket p_1 \; p_2 \rrbracket = \llbracket p_2 \rrbracket \circ \llbracket p_1 \rrbracket$$

A REPL is a monoid homomorphism between programs and their effects

REPLization in Onward!2020

Replizationis: extending a base language to a sequential variant

REPLization in Onward!2020

Replizationis: extending a base language to a sequential variant

1. De ne the syntax of the extended languagph(rases/ entry points)

REPLization in Onward!2020

Replizationis: extending a base language to a sequential variant

1. De ne the syntax of the extended languagph(rases/ entry points)
2. Extend interpreter by linking phrases to functions in base interpreter

REPLization in Onward!2020

Replizationis: extending a base language to a sequential variant

1. De ne the syntax of the extended languagephrases/ entry points)
2. Extend interpreter by linking phrases to functions in base interpreter
3. Add phrase composition operator to the language (it is now sequential by de nition)

$$Jp_1 \quad p_2K = Jp_2K \quad Jp_1K$$

REPLization in Onward!2020

Replizationis: extending a base language to a sequential variant

1. De ne the syntax of the extended languagephrases/ entry points)
2. Extend interpreter by linking phrases to functions in base interpreter
3. Add phrase composition operator to the language (it is now sequential by de nition)

$$Jp_1 \quad p_2K = Jp_2K \quad Jp_1K$$

The e ect of one phrase on the next is determined by (2)

Onward!2020 (MiniJava case study)

REPLization of eFLINT

1. eFLINT 2.0: REPLization applied to eFLINT using eFLINT 1.0 interpreter

   valid phrases: type-declarations, initialization, triggering action/events, queries
   enables backtracking for manual exploration
   enables implementation of `eFLINT actors'
   type-declarations as phrases enable dynamic policy construction

REPLization of eFLINT

1. eFLINT 2.0: REPLization applied to eFLINT using eFLINT 1.0 interpreter

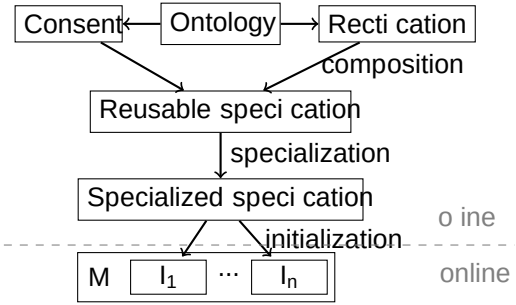
   valid phrases: type-declarations, initialization, triggering action/events, queries
   enables backtracking for manual exploration
   enables implementation of `eFLINT actors'
   type-declarations as phrases enable dynamic policy construction

2. Tools based on the same REPLized interpreter

   eflint-repl : command line tool for manual exploration and debugging
   eflint-server : server that listens on a port for incoming phrases

eFLINT actors

eFLINT integration { overview (GDPR example)



eFLINT integration { example

Reusable GDPR concepts

```
Fact controller
Fact subject

Fact data
Fact subject-of
 Identified by subject * data
```

Specialisation to application

```
Fact bank    //exactly one
Fact client //exactly one

Fact controller
 Derived from bank
Fact subject
 Derived from client

Fact data
 Identified by Int

Event data-change
 Terminates data
 Creates data(data + 1)

Fact subject-of
 Derived from
  subject-of(client,processed)
 ,subject-of(client,data)

Fact processed
 ...
```

Instantiation at run-time

```
+bank(GNB).
+client(Alice).
+data(0).
```

Derived after instantiation

```
+controller(GNB).
+subject(Alice).
+subject-of(Alice,0).
```

Modular GDPR speci cation

Figure: ICTH2021

```
Act collect-personal-data
  Actor controller
  Recipient subject
  Related to data, processor, purpose
    Where subject-of(subject, data)
  Creates processes(processor, data, controller, purpose)
```

Article 5 { processing conditions

```
Fact minimal-for-purpose Identified by processes
Extend Act collect-personal-data Conditioned by minimal-for-purpose(data, purpose)
```

Listing 4: Member (1c)

```
Fact accurate-for-purpose Identified by data * purpose
Extend Act collect-personal-data Conditioned by accurate-for-purpose(data, purpose)
```

Listing 5: Member (1d)

Article 6 { legal processing

```
Fact consent Identified by subject * controller * purpose * data
Extend Act collect-personal-data
  Holds when consent(subject, controller, purpose, data)
```

Listing 6: Member (1a)

```
Fact has-legal-obligation Identified by processes
Extend Act collect-personal-data
  Holds when has-legal-obligation(controller, purpose)
```

Listing 7: Member (1c)

Compliance questions

According to the GDPR and the DIPG regulatory document:

1. What conditions need to be ful lled by a member before making data available?

2. What conditions need to be ful lled when accessing data from the registry?

Compliance Question 1

DIPG Regulatory document { Article 4(2):

Members should transfer data to the DIPG registry in a coded form only

```
Fact coded Identified by dataset

Act make-data-available
  Actor institution
  Recipient dcog
  Related to dataset
  Conditioned by coded(dataset)
  Holds when member(institution)
```

Compliance Question 1

```
Extend Act make-data-available Syncs with (Foreach donor:
  collect-personal-data(controller = institution
                        ,subject    = donor
                        ,data       = dataset
                        ,processor  = "DCOG"
                        ,purpose    = "DIPGResearch")
    When subject-of(donor, dataset))
```

An institution can make a dataset available when (for each donor (subject) in the dataset):

- The institution is a member (DIPG Regulatory Document – Article 4(2))
- Data is coded (DIPG Regulatory Document – Article 4(2))
- Consent is given by the donor for the processing of their personal data by the DCOG for the purpose of DIPGResearch (GDPR – Article 6)
- Data should be accurate for the purpose DIPGResearch (GDPR – Article 5)

Subsection 3

Goals for eFLINT 3.0

Goals for eFLINT 3.0

Language design

Clear separation between:

- Computational concepts: actions, events, synchronisation
- Normative concepts: prohibition, obligation, permission, power

A module system, introducing namespaces and a versioning mechanism

Modular, rule-based specification as the default through implicit extensions

(eFLINT 2.0 can serve as a core/inner language to eFLINT 3.0)

Language engineering

Additional static analyses to detect inconsistencies and possible errors

Detailed reports as part of reasoning output to improve explainability

User-friendly programming environment for writing and testing specifications

Interoperability, e.g. with linked data / semantic web

Section 3

Reflections

Bounded vs open-ended domains

Static analyses

eFLINT 1.0 enabled automated scenarios assessment in finite domain

Future work: applying model checking, and/or property-based testing

Dynamic enforcement

eFLINT 2.0 enabled dynamic interpretation, qualification and assessment

Domain established at runtime, based on the contents of the knowledge base

Design decision:

When enumerating instances, first check domain of type, then knowledge base

```
// opt1: Fact person Identified by Alice, Bob, Chloe, David
// opt2: +person(Alice). +person(Bob). +person(Chloe). +person(David).

?(Forall person: !homework-due(person))
```

Two approaches to enforcing social policies

Embedding eFLINT specifications as eFLINT actors, akin to ‘policy decision point’:

Generating system-level policies, akin to ‘policy administration point’

Takeaway messages

At the Complex Cyber Infrastructure group, we are experimenting with approaches to enforcing laws, regulations, agreements and contracts in (distributed) systems

Takeaway messages

At the Complex Cyber Infrastructure group, we are experimenting with approaches to enforcing laws, regulations, agreements and contracts in (distributed) systems

The eFLINT DSL serves as a tool to demonstrate and experiment with various aspects of our approach, with a focus on runtime enforcement using `regulatory services'

Takeaway messages

At the Complex Cyber Infrastructure group, we are experimenting with approaches to enforcing laws, regulations, agreements and contracts in (distributed) systems

The eFLINT DSL serves as a tool to demonstrate and experiment with various aspects of our approach, with a focus on runtime enforcement using `regulatory services'

These experiments highlight the importance of software engineering concepts such as modularity, reuse, version control, overriding mechanisms and inheritance

Takeaway messages

At the Complex Cyber Infrastructure group, we are experimenting with approaches to enforcing laws, regulations, agreements and contracts in (distributed) systems

The eFLINT DSL serves as a tool to demonstrate and experiment with various aspects of our approach, with a focus on runtime enforcement using `regulatory services'

These experiments highlight the importance of software engineering concepts such as modularity, reuse, version control, overriding mechanisms and inheritance

The next phase is to improve the practicality and usability of eFLINT and to demonstrate our approach in data exchange systems such as the Amsterdam Data Exchange (AMdEX)

Towards a DSL for formalising laws and regulations

intermediate findings and results

L. Thomas van Binsbergen

Informatics Institute, University of Amsterdam
ltvanbinsbergen@acm.org

September 9, 2021
Strumenta, Virtual Meetup

UNIVERSITY OF AMSTERDAM