Modularity in the Rule Interchange Format

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Outline

- Motivation: the MWeb framework

- Problems identified in the Rule Interchange Format

- Negations, implication and logical entailment

- Document Formulas in the Rule Interchange Format

- Conclusions

Motivation

- Knowledge in the Semantic Web must be shared and modularly organised.

- The MWeb framework provides general mechanisms to specify modular rulebases in the Semantic Web, with a working implementation supporting some of the Rule Interchange Format (RIF) constructs.

- We need a standard syntax and semantics to foster interoperability of MWeb rulebases.

Obvious Next Step: define MWeb as a specialization of the RIF Framework For Logic Dialects (RIF-FLD).

MWeb

- Contextualized and global interpretation of arbitrary predicates.
- Explicit control of monotonicity and non-monotonicity.
- Scoped open and closed world assumptions.
- Separate interface and implementation of rulebases with modular and independent compilation and loading.
- Two semantics defined with a solid theory based on the two major semantics of extended logic programming.

We require from RIF nine of the eleven types of terms, including standard boolean binary connectives, implication, weak and strong negation, and document formulas.

A glimpse of syntax (interface geo.mw)

:- rulebase 'http://geography.int'.

:- prefix geo='http://geography.int#'.

:- import('rdf.mw',interface).

:- defines local closed class(geo:Continent).

:- defines local open class(geo:Country)
                          wrt context class(geo:PoliticalEntity).

:- defines local definite class(geo:City), class(geo:PoliticalEntity).

:- defines local definite property(geo:located_in),
                          property(geo:part_of),
                          property(geo:city_name).

A glimpse of syntax
(logic document geo.rb)

:- import('rif.rb', rulebase).

:- import('rdf.rb', rulebase).

geo:Africa # geo:Continent.

geo:America # geo:Continent.

geo:Antarctica # geo:Continent.

geo:Asia # geo:Continent.

geo:Europe # geo:Continent.

geo:Oceania # geo:Continent.

geo:Country ## geo:PoliticalEntity.

geo:EU.[geo:part_of -» geo:Europe,
        rdf:type -» geo:PoliticalEntity].

?X.[geo:located_in -» ?Z] :- ?Y.[geo:part_of -» ?Z], ?X.[geo:located_in -» ?Y].

geo:Spain.[geo:part_of -» geo:EU,
          rdf:type -» geo:Country].

geo:Portugal.[geo:part_of -» geo:EU,
             rdf:type -» geo:Country].

geo:Cataluna.[geo:part_of -» geo:Spain,
             rdf:type -» geo:PoliticalEntity].

geo:Barcelona.[geo:located_in -» geo:Cataluna,
              rdf:type -» geo:City,
       geo:city_name -» "Barcelona"^^xsd:string].

geo:Lisboa.[geo:located_in -» geo:Portugal,
           rdf:type -» geo:City,
           geo:city_name -» "Lisboa"^^xsd:string,
           geo:city_name -» "Lisbon"^^xsd:string].

Hidden negations

Closed Predicates

neg ?X # geo:Continent :-
?X # mw:Vocabulary,
naf ?X # geo:Continent

Open Predicates

neg ?X # geo:Country :-
?X # geo:PoliticalEntity,
naf ?X # geo:Country.

?X # geo:Country :-
?X # geo:PoliticalEntity,
naf neg ?X # geo:Country.

A glimpse of syntax
(interface inst.mw)

:- rulebase 'http://institution.int'.

:- prefix geo='http://geography.int#'.

:- prefix inst = 'http://institution.int#'.

:- import('rdf.mw',interface).

:- defines local normal class(inst:Institution).

:- defines local normal
        inst:address(?ID,?NAME,?STREET,?NUMBER,?CITY,?COUNTRY).

:- uses definite class(geo:Country).

:- uses definite property(geo:located_in), property(geo:city_name).

:- uses definite property(rdf:type) from 'http://geography.int#'.

A glimpse of syntax
(logic document inst.rb)

```
:- import('rdf.rb', rulebase ).

:- defines internal definite inst:address/5.

?ID # inst:Institution :- inst:address( ?ID, ?_, ?_, ?_, ?_ ).


inst:address(inst:UBAR,"Universitat Barcelona"^^xsd:string,
            "Calle 1"^^xsd:string, 2, "Barcelona"^^xsd:string).
inst:address(inst:UNL, "Universidade Nova de Lisboa"^^xsd:string,
            "Rua 2"^^xsd:string, 3, "Lisboa"^^xsd:string).


inst:address(?ID,?NAME,?STREET,?NUMBER,?CITY,?COUNTRY) :-
        inst:address(?ID,?NAME,?STREET,?NUMBER,?CITYNAME),
        ?CITY.[ geo:city_name -» ?CITYNAME ],
        ( ?CITY.[ geo:located_in -» ?COUNTRY ] ) @ 'http://geography.int',
        (?COUNTRY.[ rdf:type -» geo:Country ] ) @ 'http://geography.int'.
```

Initial plan…

- RIF-FLD offers all the constructs to encode MWeb:

  1. Has document formulas to capture the notion of "modules";

  2. Has weak negation;

  3. Has strong negation;

  4. Has a rule symbol (implication)

  5. Defines logical entailment

- RIF-FLD defines a many-valued general semantics for these constructs capturing several important logical-based rule languages.

… but things turned out differently

- Modules:
  - No definition of interfaces
  - Incorrect handling of dependencies of import and module mechanisms

- Connectives
  - Weak negation (naf) semantics is too restrictive
  - Implication has similar problems

- Logical entailment
  - The problems with implication have effects also in the notion of model and logical entailment

We propose solutions to all these issues being at the same time backward compatible with existing RIF-FLD dialects.

Truth-values and semantic structures

- Each RIF dialect must define a set of truth-values **TV**

  - **TV** must be a complete lattice defining a partial order $\leq_t$

  - **TV** has two distinguished elements **f** and **t**, the bottom and top elements.

  - **TV** has a negation operator $\sim$: **TV** $\rightarrow$ **TV** such that:

    1. $\sim \sim x = x$

    2. $\sim t = f$ and $\sim f = t$

- Semantic structures assign meaning to RIF-FLD terms and formulas

Interpretation of connectives

- Conjunction: interpreted as greatest lower bound in TV

- Disjunction: interpreted as least upper bound in TV

- Negations:
  - $TVal_I(\text{Neg Neg } \phi) = TVal_I(\phi)$
  - ~~$TVal_I(\text{Naf } \phi) = \sim TVal_I(\phi)$~~

- Implication:
  - $TVal_I(head :\!\!- body) = \mathbf{t}$, if $TVal_I(head) \geq_t TVal_I(body)$.
  - ~~$TVal_I(head :\!\!- body) <_t \mathbf{t}$, otherwise.~~

Standard semantics for extended logic programming are ruled out by RIF-FLD since do not obey to the restrictions imposed!

Equilibrium Logic (ASP)

$$TV = \{ -2 <_t -1 <_t 0 <_t +1 <_t +2 \}$$

$\rightarrow$	-2	-1	0	+1	+2
-2	+2	+2	+2	+2	+2
-1	+2	+2	+2	+2	+2
0	+2	+2	+2	+2	+2
+1	-1	-1	0	+2	+2
+2	-2	-1	0	+1	+2

	~
-2	+2
-1	+2
0	+2
+1	-1
+2	-2

	-
-2	+2
-1	+1
0	0
+1	-1
+2	-2

Partial Equilibrium Logic (WFS), Infinite valued semantics (WFS) and Nine Logic (WFSXp) also falsify (some) conditions of RIF-PRD.

Alternative semantics

- ## Weak Negation

  - Enforce solely anti-monotonicity of negation

    $\sim$: **TV** $\rightarrow$ **TV** such that if $x <_t y$ then $\sim y <_t \sim x$, for any $x,y \in$ **TV**

- ## Implication:

  - $TVal_I(head \text{ :- } body) = \mathbf{t}$, if $TVal_I(head) \geq_t TVal_I(body)$.
  - Drop the second condition

All the mentioned logics satisfy these natural conditions.

Models and Logical Entailment (RIF-FLD)

- Model:

  Let **I** be a semantic structure or multi-structure. We say that **I** is a ***model*** of a formula ϕ, written as **I** $|=\phi$, iff $TVal_I(\phi) =$ **t**.

- Logical Entailment:

  Let ϕ and ψ be RIF-FLD formulas. We say that ϕ ***entails*** ψ, written as $\phi \models \psi$, if and only if for every intended semantic multi-structure $\hat{I}$ of ϕ it is the case that $TVal_{\hat{I}}(\phi) \leq_t TVal_{\hat{I}}(\psi)$.

Nine Logic (WFSXp) and Equilibrium Logic (ASP) have problems with these definitions.

Models and Logical Entailment

- Designated truth-values are collected in a subset **DV** of **TV** such that t $\square$ **DV**

- Model:

  Let *I* be a semantic structure or multi-structure. We say that *I* is a *model* of a formula φ, written as *I* |=φ, iff *TVal$_I$*(φ) $\square$ **DV**

- Logical Entailment:

  Let φ and ψ be RIF-FLD formulas. We say that φ *entails* ψ, written as φ |= ψ, if and only if for every intended semantic multi-structure Î of φ it is the case that Î |= ψ :- φ (or, if you prefer Î |= φ → ψ).

In the original RIF-FLD semantics we have that Î |= ψ :- φ
iff $TVal_I$(ψ :- φ) = t iff $TVal_I$(ψ) $\geq_t$ $TVal_I$(φ) iff $TVal_I$(φ) $\leq_t$ $TVal_I$(ψ)

Rendering of a MWeb interface

(* *NO WAY TO ASSIGN AN IDENTIFIER TO THIS DOCUMENT* *)
Document(

   Dialect(MWeb)

   Base(<http://institution.int>)

   Prefix(geo <http://geography.int#>)

   Prefix(inst <http://institution.int>)

   Import(<file://somepath/rdf.mw>)

   Module(<http://geography.int> <http://geography.int/inst.mw>)

   Group(*The interface declarations come here*)

)

Imported and linked relations

ruleml2011.rb

```
Document(
  Module( ppl 'people.rb' )
  …
)
```

geo.rb

```
Document(
  Import( 'rif.rb' )
  Import( 'rdf.rb' )
  …
)
```

rdf.rb

```
Document(
  Import( 'rif.rb' )
  …
)
```

people.rb

```
Document(
  Import( 'inst.rb' )
  …
)
```

inst.rb

```
Document(
 Import( 'rdf.rb' )
 Module( geo 'geo.rb' )
…
)
```

rif.rb

```
Document(
  …
)
```

Directly Linked

Directly imported
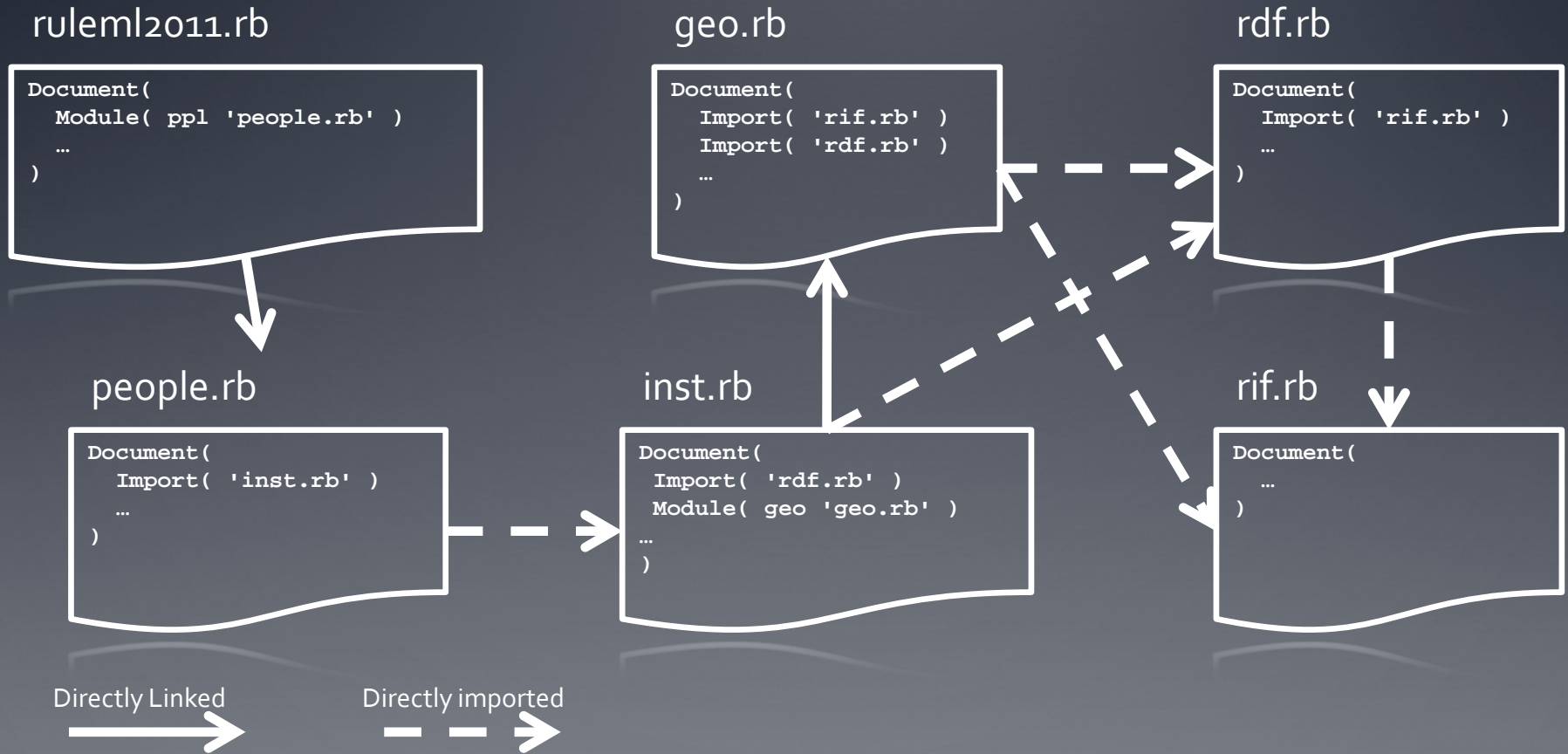
RIF-FLD semantic multi-structures

ruleml2011.rb
```
Document(
  Module( ppl 'people.rb' )
  …
)
```

geo.rb
```
Document(
  Import( 'rif.rb' )
  Import( 'rdf.rb' )
  …
  Group( … )
)
```

rdf.rb
```
Document(
  Import( 'rif.rb' )
  …
  Group( … )
)
```

people.rb
```
Document(
  Import( 'inst.rb' )
  …
  Group( … )
)
```

inst.rb
```
Document(
  Import( 'rdf.rb' )
  Module( geo 'geo.rb' )
  …
  Group( … )
)
```

rif.rb
```
Document(
  …
  Group( … )
)
```

$$\hat{I}_{inst} = < D_{inst}, G_{inst}, I^{rdf.rb}, I^{rif.rb}, M^{geo.rb} >$$
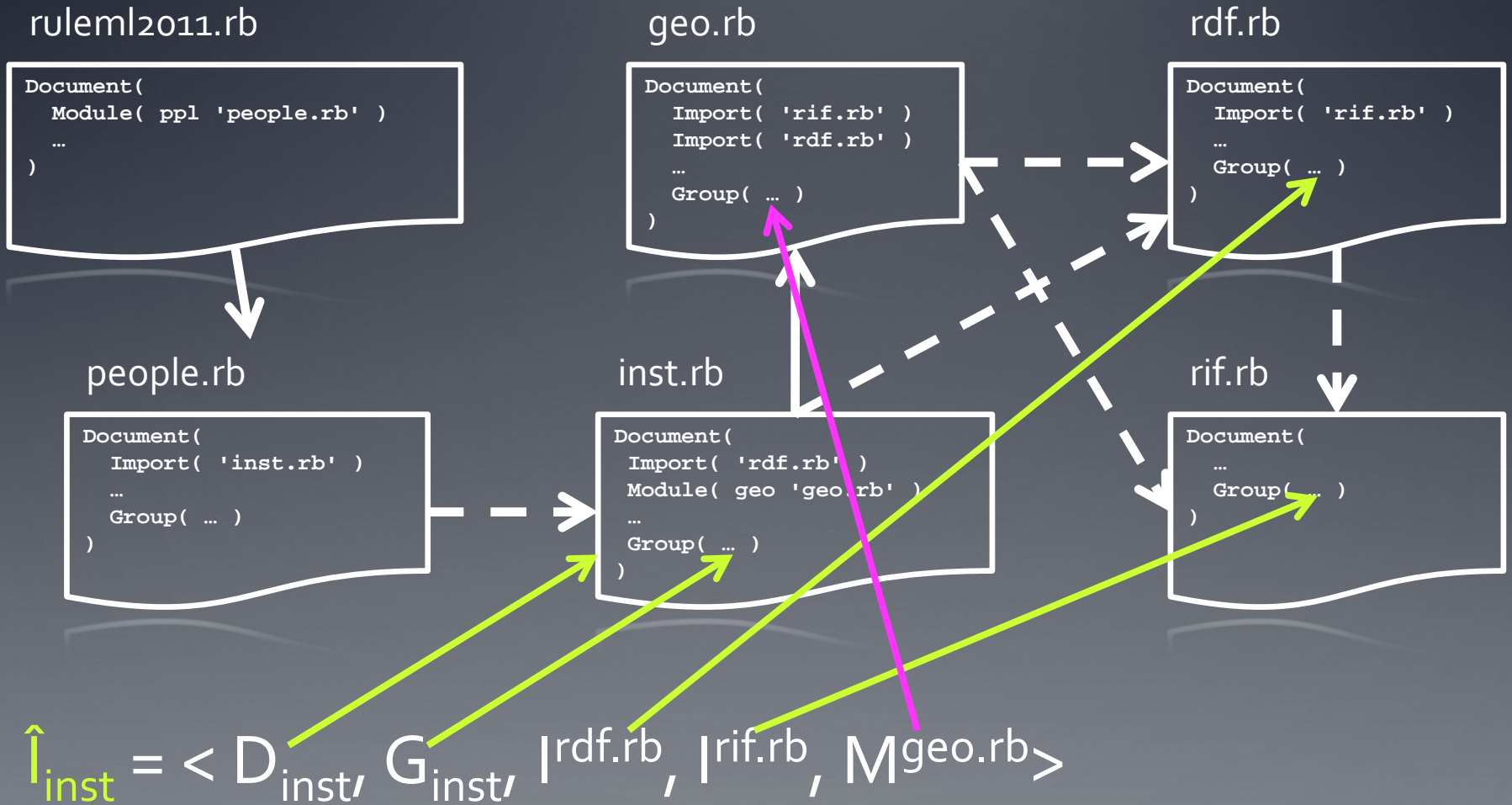
Shared interpretations...

ruleml2011.rb

```
Document(
  Module( ppl 'people.rb' )
  …
)
```

geo.rb

```
Document(
  Import( 'rif.rb' )
  Import( 'rdf.rb' )
  …
  Group( … )
)
```

rdf.rb

```
Document(
  Import( 'rif.rb' )
  …
  Group( … )
)
```

people.rb

```
Document(
  Import( 'inst.rb' )
  …
  Group( … )
)
```

inst.rb

```
Document(
  Import( 'rdf.rb' )
  Module( geo 'geo.rb' )
  …
  Group( … )
)
```

rif.rb

```
Document(
  …
  Group( … )
)
```

$$\hat{I}_{inst} = < D_{inst}, G_{inst}, I^{rdf.rb}, I^{rif.rb}, M^{geo.rb} >$$
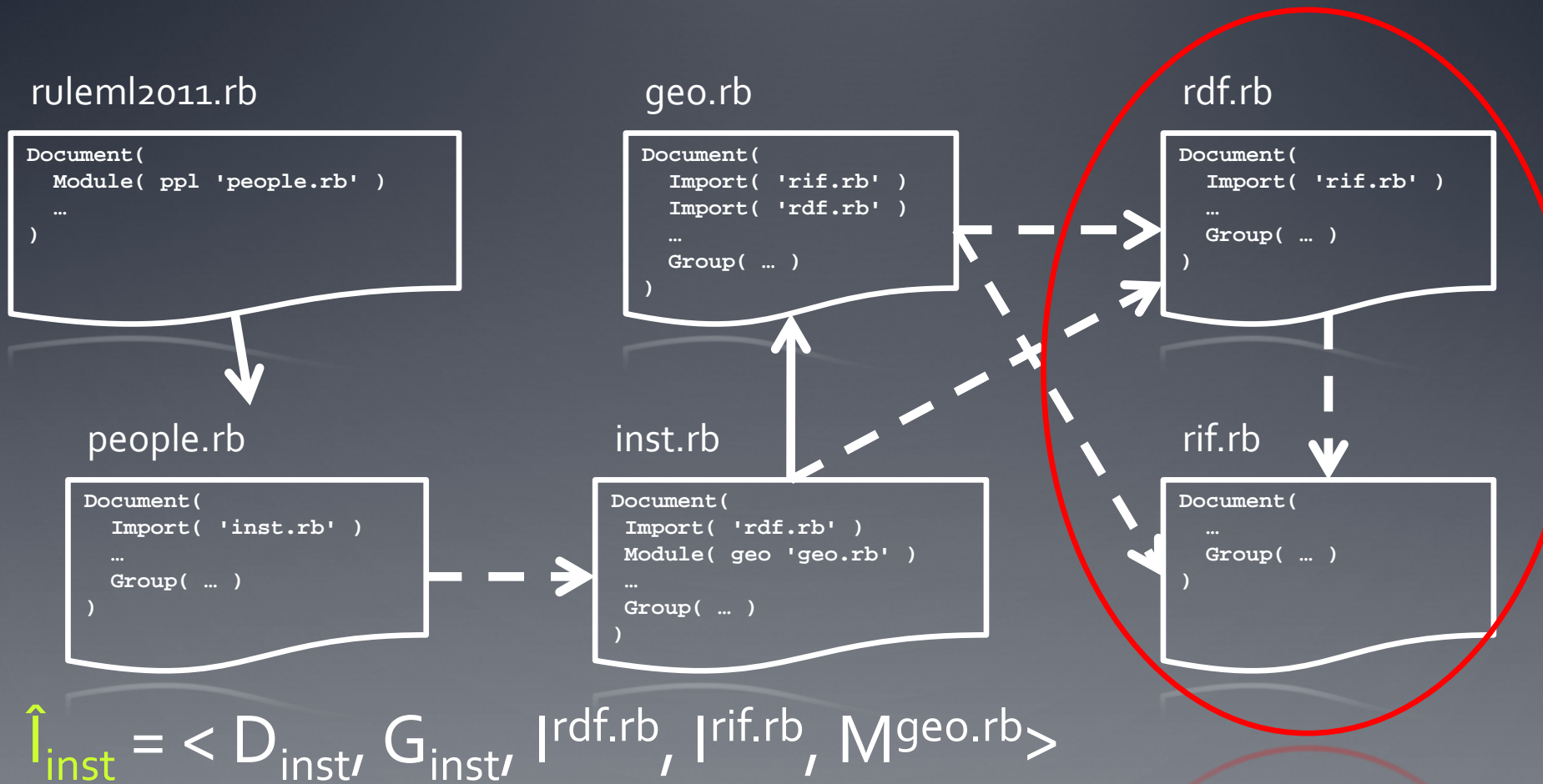
Missing interpretations...

$$\hat{I}_{ruleml2011} = < D_{ruleml2011}, G_{ruleml2011}, M^{people.rb} >$$

ruleml2011.rb

```
Document(
  Module( ppl 'people.rb' )
  …
)
```

geo.rb

```
Document(
  Import( 'rif.rb' )
  Import( 'rdf.rb' )
  …
  Group( … )
)
```

rdf.rb

```
Document(
  Import( 'rif.rb' )
  …
  Group( … )
)
```

Dependency relations in RIF-FLD are independent!

people.rb

```
Document(
  Import( 'inst.rb' )
  …
  Group( … )
)
```
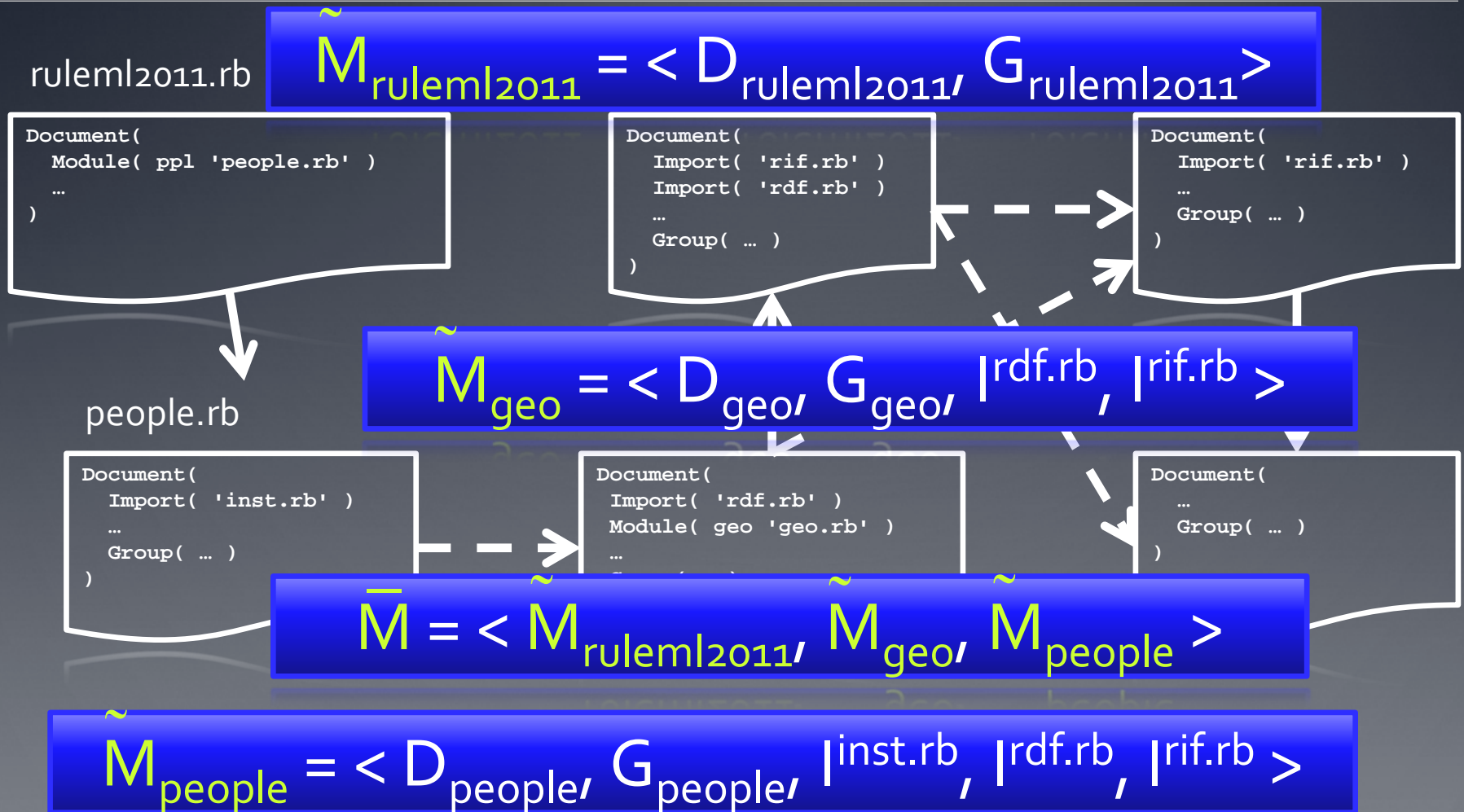
inst.rb

```
Document(
  Import( 'rdf.rb' )
  Module( geo 'geo.rb' )
  …
  Group( … )
)
```

rif.rb

```
Document(
  …
  Group( … )
)
```

$$\hat{I}_{people} = < D_{people}, G_{people}, I^{inst.rb}, I^{rdf.rb}, I^{rif.rb} >$$

Our proposal

$$\tilde{M}_{ruleml2011} = \langle D_{ruleml2011}, G_{ruleml2011} \rangle$$

ruleml2011.rb

```
Document(
  Module( ppl 'people.rb' )
  …
)
```

```
Document(
  Import( 'rif.rb' )
  Import( 'rdf.rb' )
  …
  Group( … )
)
```

```
Document(
  Import( 'rif.rb' )
  …
  Group( … )
)
```

$$\tilde{M}_{geo} = \langle D_{geo}, G_{geo}, I^{rdf.rb}, I^{rif.rb} \rangle$$

people.rb

```
Document(
  Import( 'inst.rb' )
  …
  Group( … )
)
```

```
Document(
  Import( 'rdf.rb' )
  Module( geo 'geo.rb' )
  …
```

```
Document(
  …
  Group( … )
)
```

$$\bar{M} = \langle \tilde{M}_{ruleml2011}, \tilde{M}_{geo}, \tilde{M}_{people} \rangle$$

$$\tilde{M}_{people} = \langle D_{people}, G_{people}, I^{inst.rb}, I^{rdf.rb}, I^{rif.rb} \rangle$$

Conclusions

- We have identified several issues in the semantics as specified in the RIF-FLD recommendation.

- We have adapted the semantics such that the main recent logics for (extended) logic programming are not ruled out.

- We have changed the way semantic structures for multi-documents are constructed in order to solve several problems of RIF-FLD semantics.

Future work

- Provide a full syntactic alignment of the MWeb framework with the RIF-FLD, in particular the interface part.

- Define the semantics of MWeb by specialization of the RIF-FLD semantics as proposed here.

- Extend the semantics of RIF-FLD multi-document structures lifting the restriction of equal vocabulary (constants) among all documents.

- Design mechanisms to allow definition and importing of vocabularies among documents.

- Explore relationships to Multi-Context systems.

- Update the existing implementation available at http://centria.di.fct.unl.pt/~cd/mweb to support RIF documents.