Ontology Driven Software Development with Mercury

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Based on SWESE '07 paper "Ontology Driven Software Engineering for Real Life Applications"

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Outline

1. Motivation and History
2. Architecture Overview
3. OWL
4. Mercury
5. OWL -> Mercury (Hedwig)
6. Use Case: eInsurance Application

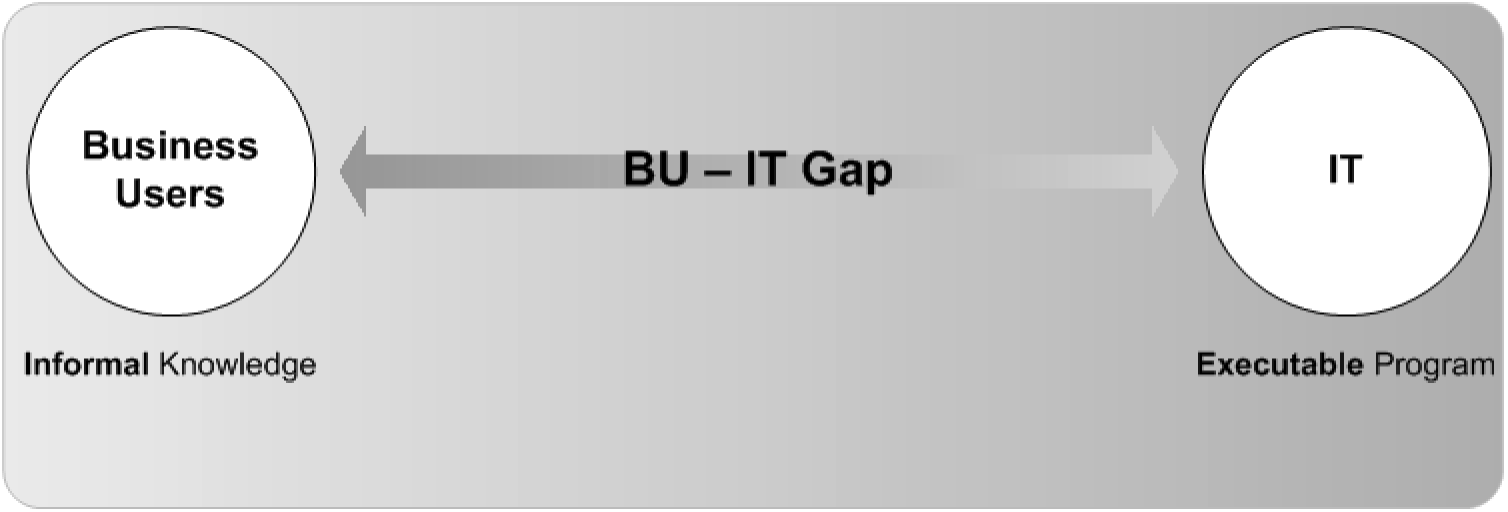
The Company at a Glance

- Mission Critical
  - Software Consultancy Firm
  - SME: 15 software engineers (MSc, PhD in CS)
  - Founded in 1993
  - Origins in **Logic Programming** (BIM Prolog)
  - Two offices: **Brussels** (Belgium) and **Melbourne** (Australia)
  - Building **Business-Critical**, **Customer-Facing** Applications
  - Customers: **Information Intensive** Companies (Insurance, Banking, Telecommunications… and Government)

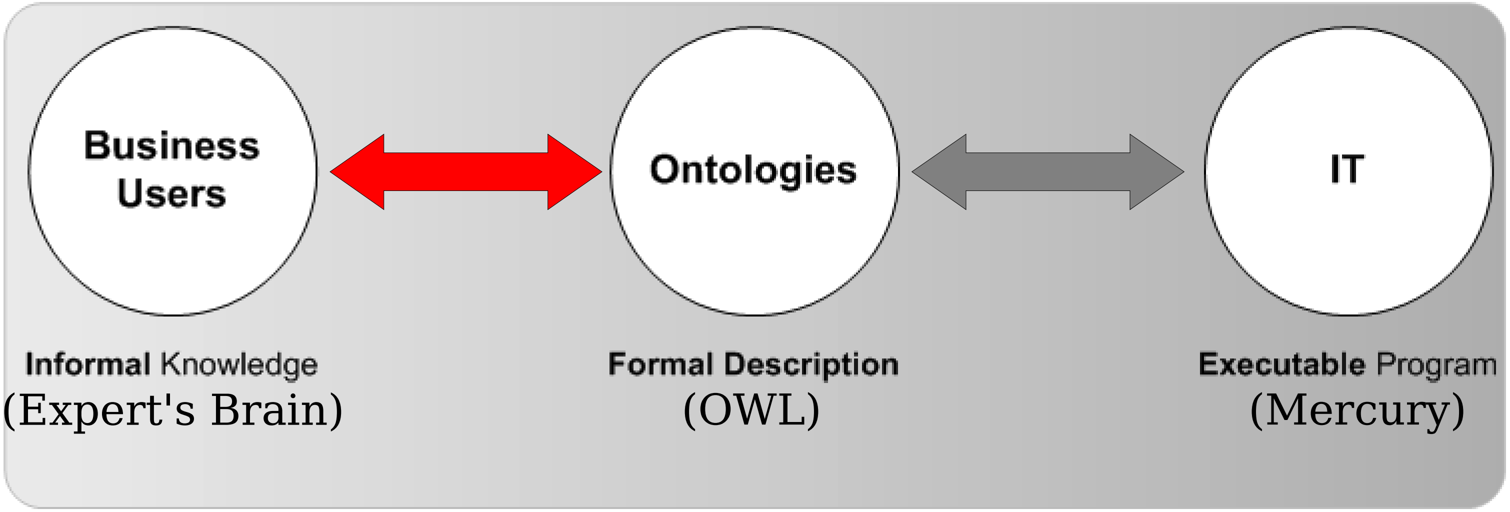
Motivation

- **Software development hard**
  - Hard to write correct software.
  - Often a difference between what the client wants and what the programmer thinks the client wants.
  - Hard to maintain software as specs change.
  - Hard to deliver software predictably in terms of cost and time.

Gap between users and programmers



Using Ontologies to help bridge the gap.



Benefits of OWL as a Modelling language

- Business feels more involved in project.
- Makes **requirements explicit**
  - Business people understand better the complexity of their domain
  - Better time and cost estimates
  - Early feedback, helps with project management
- **Simple Formal semantics**
  - Provide an unambiguous "**contract**" between Business and IT
- Long Term Business Asset
  - Ontologies not tied to a particular technology
  - Knowledge not lost in code
- W3C Standard

OWL

- **W**eb **O**ntology **L**anguage
- Formal description of a domain
  - Classes (sets of individuals)
    - Class Toys
  - Individuals (elements of classes)
    - http://toys.com.au/toys.owl#buzzLightYear is an element of Toys
  - Properties (binary relations)
    - number_of_batteries(buzzLightYear, 2)
    - married_to(harry, sally)
  - Datatypes (XML Schema)
    - string, float, int, 1..10

OWL Classes

- SubClass Hierachy (subset relations)
- Union, Intersection, Complement
- Can assert individuals are members of Classes
- Example:
  - Class ElectronicToys
  - ElectronicToys is a subclass of Toys
  - Individual buzzLightyear is a member of ElectronicToys
  - AnnoyingElectronicToys is the intersection of AnnoyingToys and ElectronicToys.

OWL Properties

- Domains must be a class
- Ranges can be a Class or a Datatype
  - Examples:
    - Property designer has domain Toy and range Person.
    - Property number_of_batteries has domain ElectronicToy and range positive integer.
- Cardinality constraints
  - Examples:
    - Each Toy should have at least one designer (but maybe more).
    - Every ElectronicToy should have exactly one value for their number_of_batteries property.

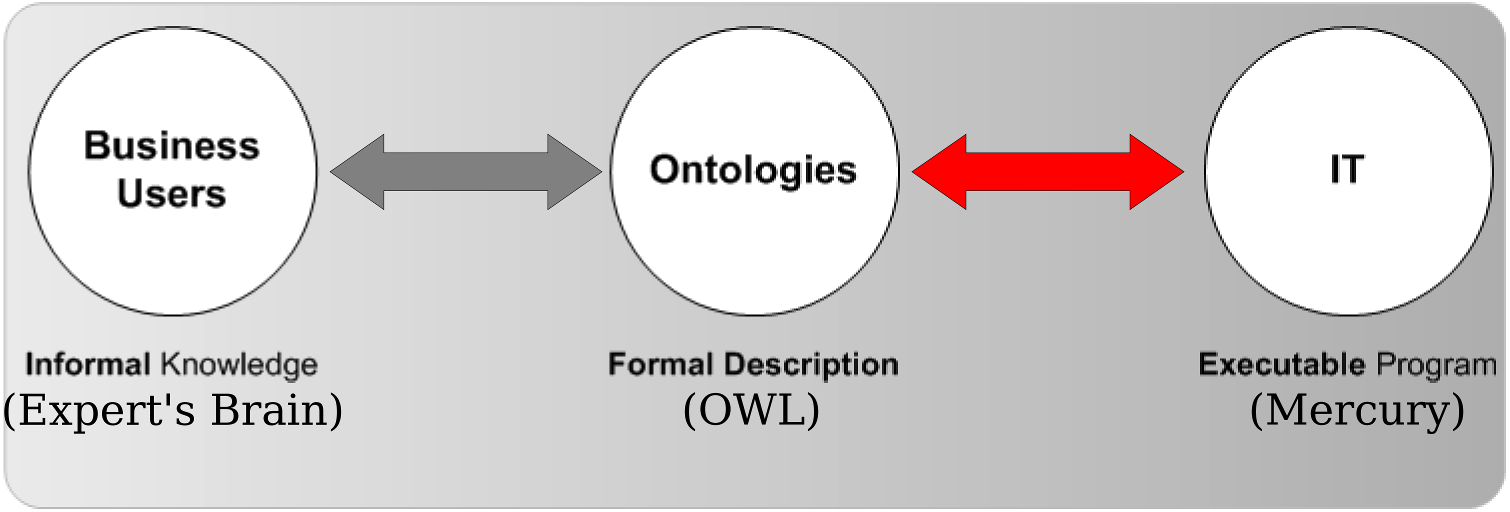
OWL Properties (cont.)

- Range constraints
  - Examples:
    - Any OldToy should have a manufactured_year of less than 1960.
    - At least one designer of a Toy should be a member of the class ImaginativePerson.
- Transitive, Symmetric, Functional, Inverse Functional, InverseOf
  - Examples:
    - older_than is a Transitive property
    - married_to is a Symmetric property
    - wife is the inverse of husband

Limitations of OWL

- Not wide spread and not well-known (although gaining traction).
- Open world assumption makes working with negation and aggregation difficult.
- OWL does not assume unique names, which complicates reasoning (we have adopted UNA).
- Limited expressiveness, although can be extended with SWRL.
- **So far, expressive enough in practice.**

Using Ontologies to help bridge the gap.



Requirements for a Mercury OWL API

- Ontologies should be integrated into the build system for the application. Should **not** just be passive documentation.
- **Compile-time** errors, not runtime errors (like a lot of RDMS APIs that use SQL query strings).
- Spec changes -> code changes.
- Mercury has a lot of compile-time checking features which we can exploit.

Mercury

- Developed at Melbourne University.
- Logic Language with similar semantics and syntax to pure Prolog.
- Added benefits of strong type, mode and determinism systems.
- Module system.

Mercury (cont.)

- Pros
  - Good engineering tool for developing large -scale robust applications.
  - Many compile time-checking features.
  - Efficient.
- Cons
  - Not widely known, therefore difficult to sell.
  - Requires experts to maintain. Risky for businesses.
- Try to ease client's fears by coding business logic in OWL, a W3C standard, and writing domain specific interpreters for the ontologies in Mercury.

Mercury API for OWL

- Generate binary predicates for properties (after infering all entailed facts from ontology):

```
:- pred number_of_batteries(uri, int).
number_of_batteries("buzzLightYear", 2).

:- pred designer(uri, uri).
designer("buzzLightYear", "janet").
designer("barbie", "sarah").
designer("lego", "harry").
```

Mercury API for OWL (cont.)

- For each class we generate an inst:

```
:- inst 'Toys'
    --->    "buzzLightYear"
    ;       "barbie"
    ;       "lego".


:- inst 'ElectronicToy'
    --->    "buzzLightYear".


:- inst 'EducationalToys'
    --->    "lego".
```

Mercury API for OWL (cont.)

- We use these insts in the mode declarations of the predicates.
- Mode declarations give information about how a predicate can be called.
- Determinism comes from cardinality restrictions.

```
:- mode number_of_batteries(in('ElectronicToy'), out) is det.

:- mode designer(in('Toy'), out('Person')) is multi.

:- mode designer(in('EducationalToy'), out('Teacher')) is det.
```

Mercury API for OWL (cont.)

- For classes we also generate a unary predicate:

```
:- pred 'Toy'(uri).
:- mode 'Toy'(ground >> 'Toy') is semidet.
:- mode 'Toy'(out('Toy')) is multi.

'Toy'(“buzzLightYear”).
'Toy'(“barbie”).
'Toy'(“lego”).
```

Example code

- Some example code using the API:

```
:- pred fulfill_order(uri::in('Item'), ...) is det.

fulfill_order(Item, ...) :-
    ( if 'Toy'(Item) then
        ( Item = “barbie”,
            ... code for ordering barbie ...
        ; Item = “lego”,
            ... code for ordering lego ...
        ; Item = “buzzLightYear”,
            number_of_batteries(Item, Batteries),
            ... code for ordering buzz with batteries ...
        )
    else
        ... code for ordering other items ...
    ).
```

Actual API a bit more complex, because...

- No empty inst in Mercury, so this only works for non-empty classes. Most classes will be empty in initial development stage.
- Subtype insts not supported very well in Mercury standard library.
- Some classes and properties may change at runtime.

Real API

- Abstract type for each OWL class
- Typeclass for each OWL class
- Functions for converting between type and uri of the right inst
- Casting predicates
- “snapshot” argument for classes and properties that change at runtime.

```
:- type 'Toy'.

:- typeclass 'Toy'(T).

:- instance 'Toy'('Toy').

:- instance 'Toy'('ElectronicToy').

:- pred designer(T::in, 'Person'::out) is multi <= 'Toy'(T).
```

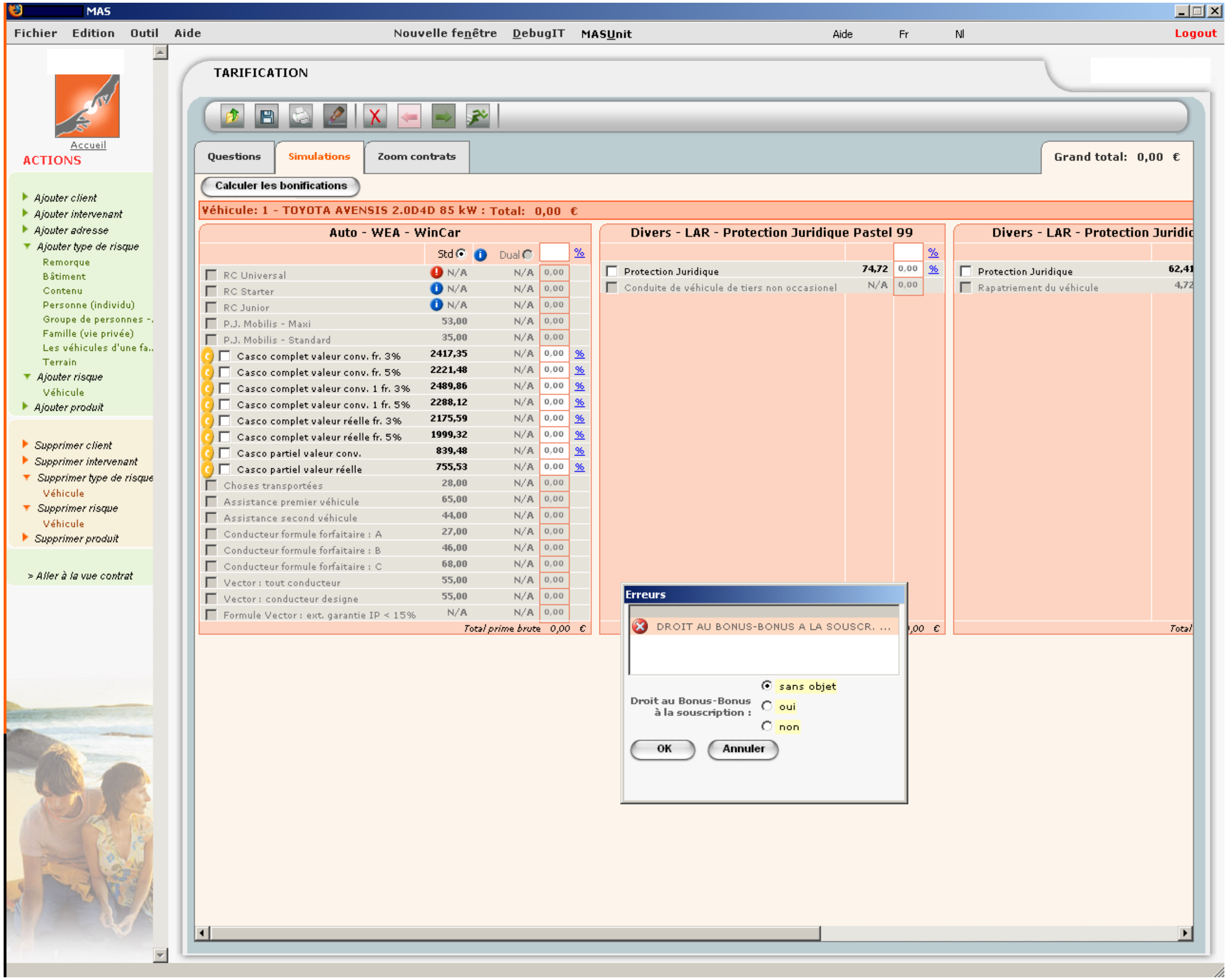
Non-Toy Application

- What?
  - eInsurance, “Non-Life”, Business Transaction at Point of Sales
  - 4000+ Brokers, Agents, Partners, Clients
  - Key selling point: fully dynamic “Shopper Screen”
  - Maximize “Straight Through Processing” $\Rightarrow$ Many rules
  - Dynamic roles, powers, preferences
  - Reuse back-ends systems for some back-office functions
- Key Development Constraint
  - Only **35% of requirements** known at kick-off

Result

- All requirements accepted (Shopper Screen refused by others)
- **OWL**, **RDF**, **Mercury**, DSL **Interpreter** (Rules), **AJAX** UI (XUL)…
- **Semantic Service Broker** based on **OWL-S** for back-ends
- **Scalable** stateless application engine, < 3 sec response time
- **Portable**: Windows, Linux, Unix, MacOS
- Development team: **10** (MC) + **2** (Customer)
- Completed in **1/3** person-months (p.m) of the next closest quote
- Completed in **1/3** p.m for a similar application (1.5 MLOC of Java)
- **45 KLOC** (program), **212 classes** + **40 K instances** (ontology)

Running Application



Questions
&
Comments