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Ontology Driven Software Development with Mercury

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

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**

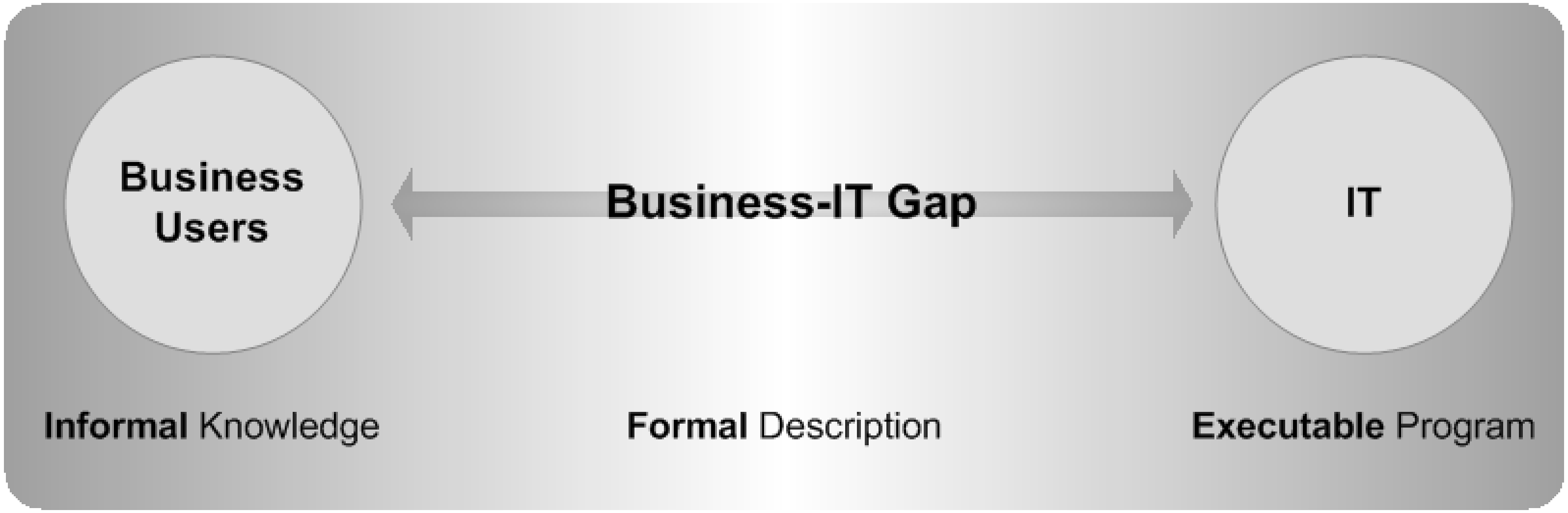
What	Software Consultancy Firm
Who	Software Engineers with a formal CS background (MSc, PhD)
When	Founded in 1993
Where	**Brussels** (Belgium) and **Melbourne** (Australia)
Origins	Logic Programming (BIM Prolog) and Open Systems
Vision	**Much better CQFT**[1] requires a **Paradigm Shift** in SE
Products	**Business-Critical Customer-Facing** Applications
Customers	**Information Intensive** Companies

[1] Cost, Quality, Flexibility, Time

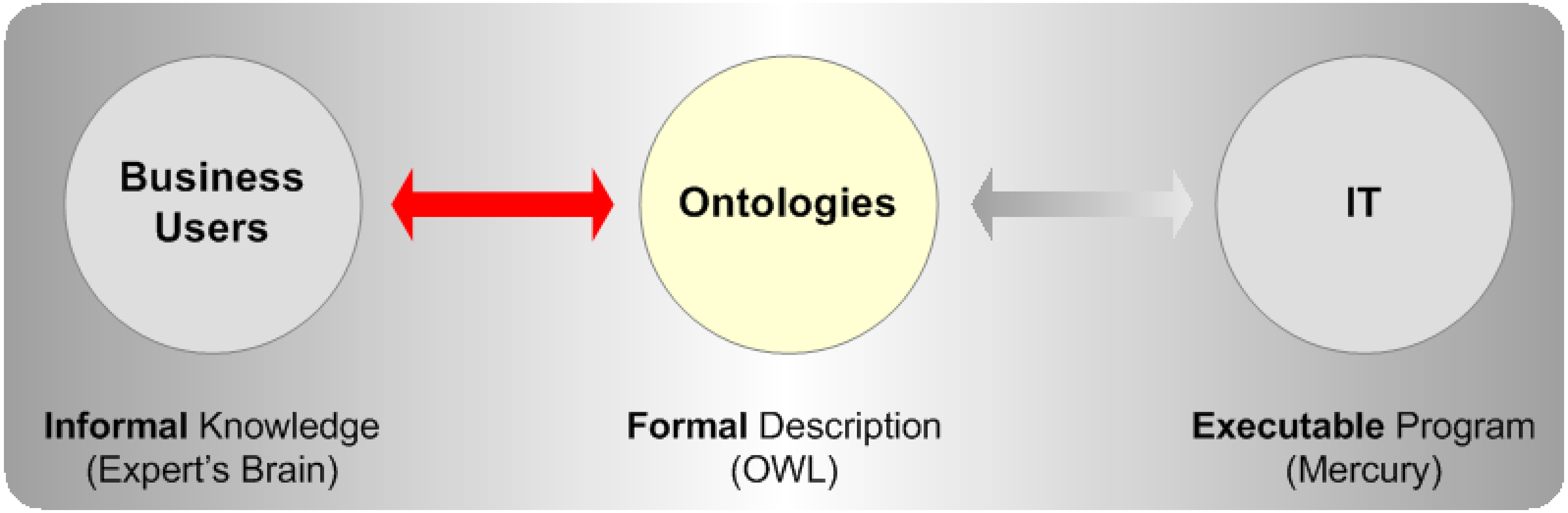
Motivation

- **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

- **Web Ontology Language**
- **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 **buzzLightyea**r 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

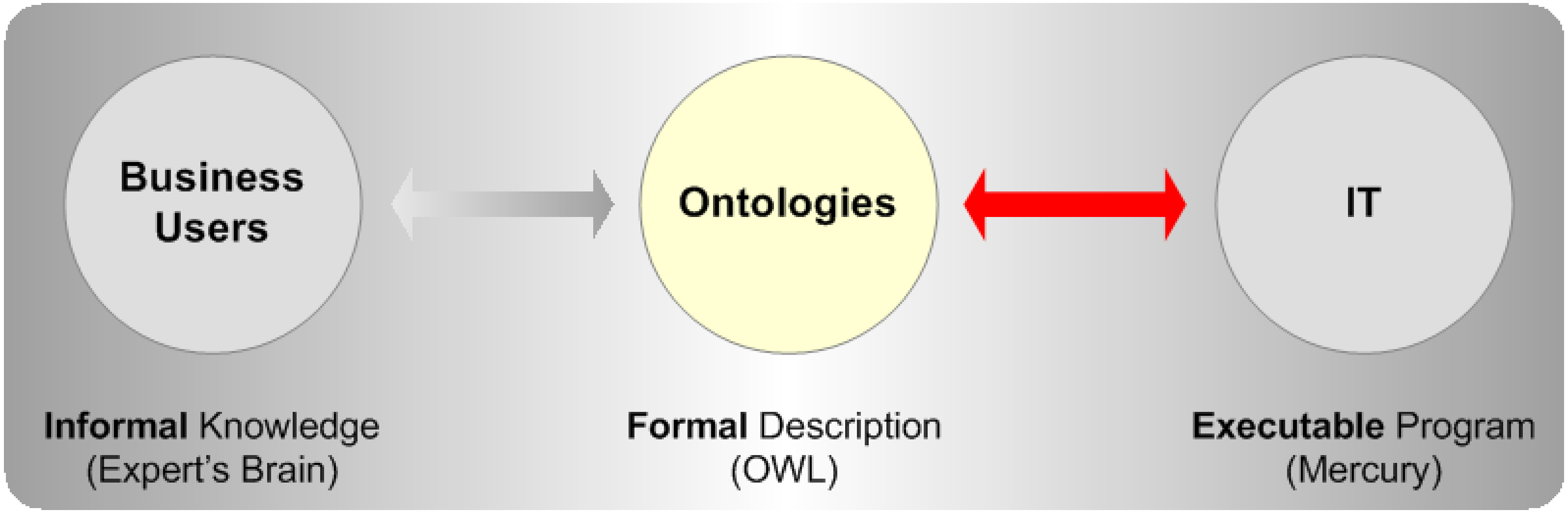
  - **older_than** is a Transitive property
  - **married_to** is a Symmetric property
  - **wife** is the inverse of **husband**

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.)

- **Pro**
  - 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, perceived as risky
- **Try to ease client's fears by**
  - Coding business logic in OWL, a W3C standard
  - Writing domain specific interpreters for the ontologies in Mercury

Mercury API for OWL

- Generate binary predicates for properties (after inferring 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).
```

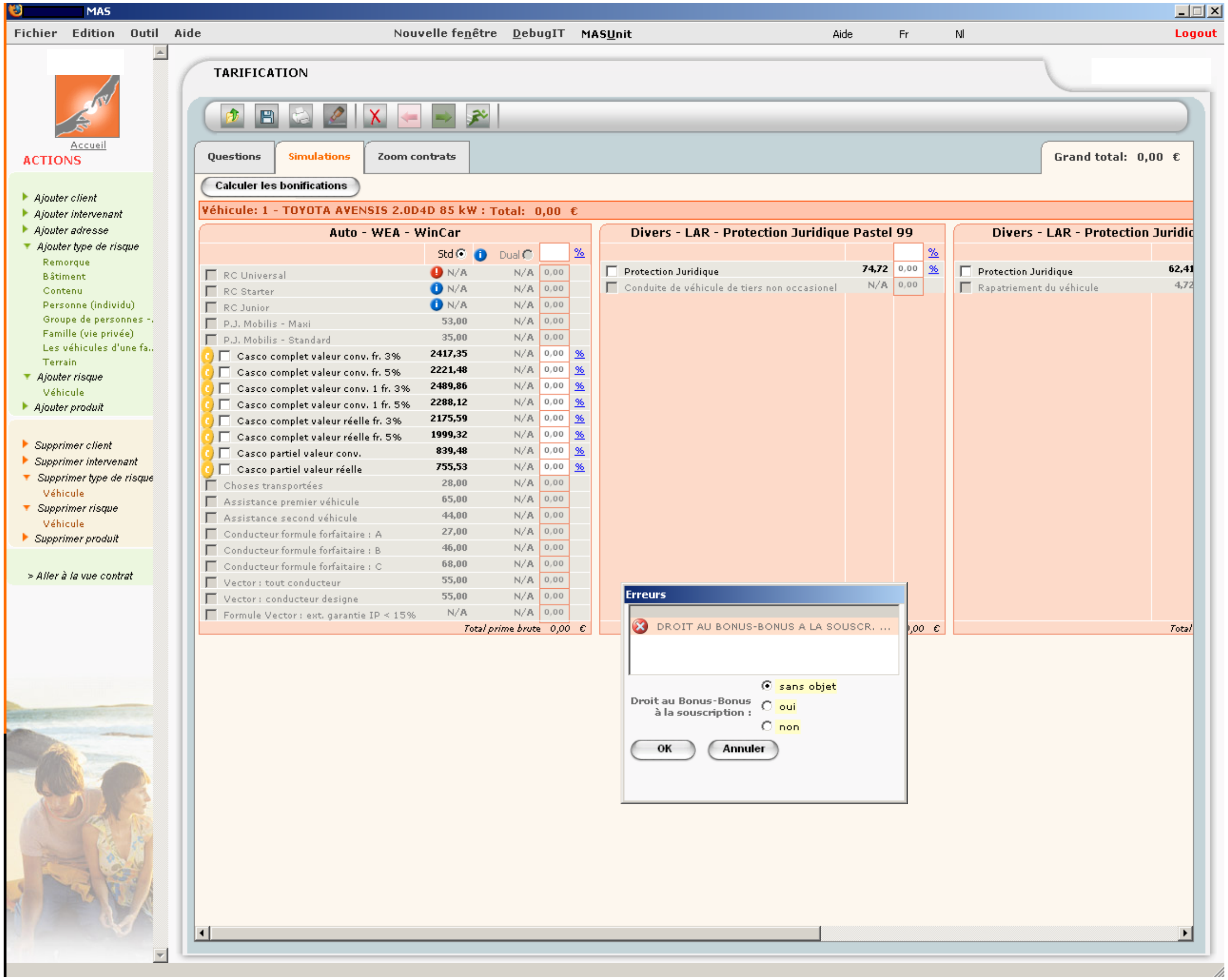
Non-Toy Application

- **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