Semantic Web Technologies

F-Logic Semantics

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Outline

F-Structures (I)

- Interpretations in F-Logic are called **F-structures**.

F-Structure

An **F-structure** is a tuple $\mathbf{I} = \langle U, \prec_U, \in_U, \mathbf{I}_F, \mathbf{I}_{\rightarrow}, \mathbf{I}_{\twoheadrightarrow} \rangle$.

- U is the domain,
- $\prec_U$ is an irreflexive partial order on U,
  - $a \preceq_U b$ when $a \prec_U b$ or $a = b$
- $\in_U$ is a binary relation over $U \times U$, and
- $a \in_U b$ and $b \preceq_U c$ then $a \in_U c$.

Interpreting Symbols with $\mathbf{I}_F$

- $\mathcal{F}$ is the set of function symbols of some F-Logic language

Interpretation of function symbols

$\mathbf{I}_F$ interprets every n-ary function symbol $f \in F$ as an n-ary function over the domain U: $\mathbf{I}_F(f) : U^n \rightarrow U$

- Thus, constants are interpreted as elements of the domain

Interpreting Attributes with $\mathbf{I}_{\rightarrow}$

Interpretation of single-valued attributes

$\mathbf{I}_{\rightarrow}$ interprets every **element of the domain** $u \in U$ as a partial function from U to U: $\mathbf{I}_{\rightarrow}(u) : U \rightarrow U$.

- Thus, $\mathbf{I}_{\rightarrow}$ associates with **elements of the domain**,
- pairs $\langle u_0, u_1 \rangle$.

Interpreting Attributes with $\mathbf{I}_{\twoheadrightarrow}$

Interpretation of set-valued attributes

$\mathbf{I}_{\twoheadrightarrow}$ interprets every **element of the domain** $u \in U$ as a partial function from U to $\mathcal{P}(U)$: $\mathbf{I}_{\twoheadrightarrow}(u) : U \rightarrow \mathcal{P}(U)$.

- Thus, $\mathbf{I}_{\twoheadrightarrow}$ associates with **elements of the domain**,
- pairs $\langle u_0, \{u_1, ..., u_n\} \rangle$.

Interpreting Variables

- Same as in FOL

Interpreting Variables

Given interpretation $\mathbf{I}$, a variable assignment B, and a term t, $t^{\mathbf{I},B}$ is defined as:

- $x^{\mathbf{I},B} = x^B$ for variable symbol x and
- $t^{\mathbf{I},B} = \mathbf{I}_F(f)(t_1^{\mathbf{I},B}, ..., t_n^{\mathbf{I},B})$ for t is $f(t_1, ..., t_n)$.

Satisfaction in F-Structures

Satisfaction of atomic formulas

Given $\mathbf{I} = \langle U, \prec_U, \in_U, \mathbf{I}_F, \mathbf{I}_P, \mathbf{I}_{\twoheadrightarrow} \rangle$, B a variable assignment, and ϕ a formula. $\mathbf{I}, B \models \phi$ if:

- $\mathbf{I}, B \models t_1 : t_2$ iff $t_1^{\mathbf{I},B} \in_U t_2^{\mathbf{I},B}$
- $\mathbf{I}, B \models t_1 :: t_2$ iff $t_1^{\mathbf{I},B} \preceq_U t_2^{\mathbf{I},B}$
- $\mathbf{I}, B \models t_1[t_2 \rightarrow t_3]$ iff $t_3^{\mathbf{I},B} = \mathbf{I}_{\rightarrow}(t_2^{\mathbf{I},B})(t_1^{\mathbf{I},B})$.
- $\mathbf{I}, B \models t_1[t_2 \twoheadrightarrow t_3]$ iff $\mathbf{I}_{\twoheadrightarrow}(t_2^{\mathbf{I},B})(t_1^{\mathbf{I},B})$ is defined and $t_3^{\mathbf{I},B} \in \mathbf{I}_{\twoheadrightarrow}(t_2^{\mathbf{I},B})(t_1^{\mathbf{I},B})$.

Extension to complex formulas

Satisfaction of Complex formulas

- $\mathbf{I}, B \models t_1 = t_2$ iff $t_1^{\mathbf{I},B} = t_2^{\mathbf{I},B}$,
- $\mathbf{I}, B \models \phi_1 \wedge \phi_2$ iff $\mathbf{I}, B \models \phi_1$ and $\mathbf{I}, B \models \phi_2$,
- $\mathbf{I}, B \models \phi_1 \vee \phi_2$ iff $\mathbf{I}, B \models \phi_1$ or $\mathbf{I}, B \models \phi_2$,
- $\mathbf{I}, B \models \neg\phi_1$ iff $\mathbf{I}, B \not\models \phi_1$,
- $\mathbf{I}, B \models \forall x(\phi_1)$ iff for every B' which is an x-variant of B, $\mathbf{I}, B' \models \phi_1$, and
- $\mathbf{I}, B \models \exists x(\phi_1)$ iff for some B' which is an x-variant of B, $\mathbf{I}, B' \models \phi_1$.

Reducing F-Logic to LP

- F-Logic Programming can be reduced to Logic Programming
- Thus, F-Logic is syntactic sugar; it does not add anything in expressiveness
- Reducing terms:
  - Map object IDs to constants
  - Map constructed terms to functions
  - Map variables to variables

  Thus, terms look exactly the same!
- Map atoms to atoms

Reducing F-Logic to LP (2)

- Each type of molecule is mapped to an atom:
  - `A:B` maps to `_member(A,B)`
  - `A::B` maps to `_subclass(A,B)`
  - `A[B->C]` maps to `_svatt(A,B,C)`
  - `A[B->>C]` maps to `_mvatt(A,B,C)`
  - `A[B=>C]` maps to `_svattsig(A,B,C)`
  - `A[B=>>C]` maps to `_mvattsig(A,B,C)`

  Note that the name of the predicates does not really matter.
- You obtain LP rules by simply replacing terms, atoms and molecules as specified.
- Axiomatize the semantics of the F-Logic is-a molecules:

```
_subclass(X,Z) :- _subclass(X,Y),_subclass(Y,Z).
 _member(X,Z) :- _member(X,Y),_subclass(Y,Z).
```


Reducing F-Logic to LP (2)

- Axiomatize the semantics of the F-Logic is-a molecules:

```
_subclass(X,Z) :- _subclass(X,Y),_subclass(Y,Z).
 _member(X,Z) :- _member(X,Y),_subclass(Y,Z).
```

- Axiomatize the semantics of the F-Logic functions:
  - `X≐Y :- _svatt(V,W,X),_svatt(V,W,Y).`
  - **or:** `!- _svatt(V,W,X),_svatt(V,W,Y), X≠Y.`

Reducing F-Logic to LP (4)

```
_member(bob, empl).
_svatt(bob,name,"Bob").
_svatt(bob,age,40).
_svatt(bob,affiliation,cs1).
_member(mary,faculty).
_svatt(mary,affilition,cs1).
_member(cs1,dept).
_svatt(cs1,dname,"CS").
_svatt(cs1,mngr,bob).

bob:empl[name->"Bob";
         age->40;
         affiliation->cs1].
mary:faculty[affiliation->cs1].
cs1:dept[dname->"CS";
         mngr->bob]].
```


Class information:

```
_svattsig(person,name,string).
_mvattsig(person,friends,person).
_mvattsig(person,children,child(person)).
_subclass(empl,person).
_svattsig(empl,affiliation,department).
_svattsig(empl,boss,empl).
_subclass(faculty,empl).
_svattsig(faculty,boss,faculty).
_svattsig(faculty,boss,manager).
_svatt(faculty,avgSalary,50000).
_svattsig(dept,mngr,empl).

person[name=>string;
      friends=>>person;
      children=>>child(person)].
empl::person[affiliation=>department;
            boss=>empl].
faculty::empl[boss=>(faculty,manager);
             avgSalary->50000].
dept[mngr=>empl].
```


Rule

```
_svatt(E,boss,M) :- _member(E,empl),_member(D,dept),
_svatt(E,affiliation,D), _svatt(D,mngr,M),
_member(M,empl).

E[boss->M] :- E:empl, D:dept,
E[affiliation->D[mngr->M:empl]].
```


Summary

Required reading

- Michael Kifer: Rules and Ontologies in F-Logic. Reasoning Web 2005: 22-34

Further reading

- Michael Kifer, Georg Lausen, James Wu: Logical Foundations of Object-Oriented and Frame-Based Languages. J. ACM 42(4): 741-843 (1995)
- Guizhen Yang, Michael Kifer: Reasoning about Anonymous Resources and Meta Statements on the Semantic Web. J. Data Semantics 1: 69-97 (2003)
- Guizhen Yang, Michael Kifer: Well-Founded Optimism: Inheritance in Frame-Based Knowledge Bases. CoopIS/DOA/ODBASE 2002: 1013-1032