

Towards a Study of Meta-Predicate Semantics

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Motivation

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- Logtalk needs to correctly compile calls to built-in meta-predicates and module meta-predicates.

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- Lack of Prolog standard meta-predicate directives and meta-predicate semantics is a portability nightmare.

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- A closure is a callable term used to construct a goal by appending one or more arguments.

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- Examples include database predicates (e.g. `assertz/1`, `retract/1`, `clause/2`) and reflection predicates (e.g. `current_predicate/1`, `predicate_property/2`).

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- Defining an exported or public meta-predicate within a module or an object allows client modules and objects to reuse predicates customized by calls to local predicates.

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foreach([], _, _).  
foreach([Element| List], Count, Goal) :-  
    \+ \+ (Count = Element, call(Goal)),  
    foreach(List, Count, Goal).
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```
fold_left(_, Result, [], Result).  
fold_left(Closure, Acc, [Arg| Args], Result) :-  
    call(Closure, Acc, Arg, Acc2),  
    fold_left(Closure, Acc2, Args, Result).
```

Meta-predicate semantics topics

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- Expressiveness of meta-predicate directives

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- Explicit qualification semantics

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- Portability of meta-predicate directives and definitions
- Meta-predicate performance
- Extending meta-predicate usefulness

Prolog meta-predicate directives

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- SWI-Prolog `module_transparent/1`

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- Other meta-arguments represented by “:” (“::” in the case of Logtalk)

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- Closures represented by non-negative integers
- Other meta-arguments represented by “:” (“::” in the case of Logtalk)
- Non meta-arguments represented by either “*” or an instantiation mode indicator (“@”, “+”, “-”, or “?”)

Limitations of the extended `meta_predicate/1` directive

- Using mode indicators in `meta_predicate/1` directives is no replacement for `mode/2` directives. An example:

```
:- meta_predicate forall(0, 0).  
:- meta_predicate setof(@, 0, -).
```

For `forall/2`, "0" means "@" but for `setof/3` "0" means "+".

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- No representation solution for meta-arguments that are sub-terms of a meta-predicate argument.

An example:

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:- meta_predicate(thread_create(0, -, :)).
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The third argument of `thread_create/3` is a list of options that may contain an `at_exit/1` goal.

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An example:

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:- meta_predicate(thread_create(0, -, :)).
```

The third argument of `thread_create/3` is a list of options that may contain an `at_exit/1` goal.

- Only the meta-predicate implementor knows how to process the “:” meta-argument!

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Execution context

This comprises both the calling context and the definition context. It includes all the information needed for the language runtime to execute a meta-predicate call.

Lookup context

This is the object or module where we start looking for the meta-predicate definition. The definition can always be reexported from another module or inherited from another object.

Explicit Qualification Semantics

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- The explicit qualification sets both the initial lookup context for the meta-predicate definition and the meta-predicate calling context. All meta-arguments that are not explicitly-qualified are called in the meta-predicate lookup context (usually the same as the meta-predicate definition context).

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- Semantics used e.g. on Ciao, Quintus Prolog, SICStus Prolog, SWI-Prolog, and YAP.
- Why? Explicit (module) qualification is seldom used. Without it, non-qualified meta-arguments are called in the meta-predicate calling context, matching user expectations.

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- Why? Same semantics for explicit and implicit qualification, matching user expectations. Non-qualified meta-arguments are always called in the meta-predicate calling context.

Explicit qualification
sets both lookup and
calling contexts

```
:- module(library, [my_call/1]).  
:- meta_predicate(my_call(0)).  
  
my_call(Goal) :-  
    write('Calling: '), writeq(Goal), nl,  
    call(Goal).  
  
me(library).
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:- module(client, [test/1]).  
  
:- use_module(library, [my_call/1]).  
  
test(Me) :-  
    my_call(me(Me)).  
  
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?- client:test(Me).  
  
Calling: client:me(_)  
Me = client  
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Calling: library:me(_)  
Me = library  
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:- object(library).  
  
:- public(my_call/1).  
:- meta_predicate(my_call(::)).  
  
my_call(Goal) :-  
    write('Calling: '), writeq(Goal),  
    nl, call(Goal), sender(Sender),  
    write('Sender: '), writeq(Sender).  
  
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:- end_object.
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- Which semantics for explicitly qualified control constructs?
- But should we really make a distinction between control constructs and meta-predicates?
- Lack of agreement on the Prolog community!

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- Control constructs in the ISO Prolog standard:
 - `call/1`, *conjunction*, *disjunction*, *if-then*, *if-then-else*, and `catch/3`
 - `true/0`, `fail/0`, `!/0`, and `throw/1`

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- Control constructs in ISO Prolog standardization proposals:
 - `call/2-N`

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$$M:(A, B) \Leftrightarrow (M:A, M:B)$$
$$M:(A; B) \Leftrightarrow (M:A; M:B)$$
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$$O::(A, B) \Leftrightarrow (O::A, O::B)$$
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`library:my_call(me(Me)) ⇔`

`library:my_call(library:me(Me))`

- No distinction between control constructs and meta-predicates is necessary!

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- Logtalk: (1) makes a distinction between control constructs and meta-predicates; (2) built-in meta-predicates are private (e.g. `call/1`, `findall/3`).
- Both solutions ensure consistency with explicit qualification semantics.

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- Meta-predicate closures must be used within a `call/2-N` built-in predicate call that complies with the corresponding meta-predicate directive.

Computational reflection support

Prolog compiler	Structural reflection built-in predicates	Behavioral reflection built-in predicates
Ciao 1.10	<code>predicate_property/2</code> (in library <code>prolog_sys</code>)	(user-defined solution possible)
ECLiPSe 6.0	<code>get_flag/3</code>	(not necessary; see <code>tool/2</code> directive)
SICStus Prolog 4.1	<code>predicate_property/2</code>	(user-defined solution possible)
SWI-Prolog 5.9.10	<code>context_module/1</code> <code>predicate_property/2</code>	<code>strip_module/3</code>
XSB 3.2	<code>predicate_property/2</code>	?????
YAP 6.0	<code>context_module/1</code> <code>predicate_property/2</code>	(user-defined solution possible)

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Quintus (*)

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:- module(m, [mp/2]).  
  
:- meta_predicate(mp(0, -)).  
  
mp(Goal, Caller) :-  
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```

ECLiPSe

```
:- module(m).  
  
:- export(mp/2).  
:- tool(mp/2, mp/3).  
  
mp(Goal, Caller,  
    Caller) :-  
    call(Goal).
```

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call/1-N control constructs

Prolog compiler	N	Notes
B-Prolog 7.4	10/65535	(interpreter/compiler – maximum arity)
Ciao 1.10	255	(maximum arity using the <code>hiord</code> library)
CxProlog 0.94.0	9	—
ECLiPSe 6.0	1	—
GNU Prolog 1.3.1	11	—
JProlog 3.0.2	5	—
K-Prolog 6.0.4	9	—
Qu-Prolog 8.10	1	(supports a <code>call_predicate/1-5</code> built-in predicate)
SICStus Prolog 4.1	255	(maximum arity)
SWI-Prolog 5.9.10	8	(<code>meta_predicate/1</code> directive limit)
XSB 3.2	11	—
YAP 6.0	12	—

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- Performance of meta-calls (native `call/2-N` implementations; avoid building temporary lists).
- Pre-processing of meta-predicate definitions (but usually only for system-provided meta-predicates).

Extending meta-predicate usefulness

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- Qu-Prolog lambda expressions

<http://www.itee.uq.edu.au/~pjr/HomePages/QuPrologHome.html>

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- **Logtalk lambda expressions**

http://logtalk.org/manuals/refman/grammar.html#grammar_lambdas

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- Most Prolog compilers without a module system don't define meta-predicate properties for built-in meta-predicates.
- `call/2-N` still missing in some Prolog compilers.
- The extended `meta_predicate/1` directive provides essential information for preventing misuse of closures.

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- Not necessary to distinguish between control constructs and meta-predicates.

Conclusions

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 - Same semantics for built-in meta-predicates and user meta-predicates.
 - Necessary to distinguish between control constructs and meta-predicates.