Computational Logic

Developing Programs with a Logic Programming System

System used in the Course

- In the course we use the **Ciao** multiparadigm programming system.
- It supports all the programming paradigms that we will study in the course:
  - ◇ For the first parts of the course, *pure logic programming* (LP):
    - * With several *search rules:*
      breadth-first, depth-first, iterative deepening, det-first, tabling, ...
    - * Also, modules can be set to *pure* mode so that impure built-ins are not accessible to the code in that module.

    This provides a reasonable approximation of pure logic programming (i.e., “Green’s dream”) –of course, at a cost in memory and execution time.
  - ◇ For other parts of the course the Ciao system supports:
    - * (ISO-)Prolog.
    - * Functional programming.
    - * Constraint programming (CLP).

Using the Ciao System

- The Ciao system includes a number of command line and graphical tools for:

  editing / compiling / debugging / verifying / optimizing / documenting / ...
- They can be used via the Playground or within IDEs such as Emacs, VSC, etc.
- Main tools:
  - ◇ Traditional, command line interactive top level (`ciaosh`).
  - ◇ Source debugger, embeddable debugger, error location, ...
  - ◇ Auto-documenter (`LPdoc`).
  - ◇ Stand-alone compiler (`ciaoc`) which can generate standalone executables.
  - ◇ Build system.
  - ◇ Scripts (architecture independent).
  - ◇ Assertions, with combined static and dynamic checking, of types, modes, determinacy, non-failure, etc. (`CiaoPP`).
  - ◇ Assertion-based unit testing and test generation (`LPtest`).

The following slides are intended as a very brief introduction to some aspects of running programs on a logic programming system. It is highly encouraged to also look at the corresponding parts of the **Ciao manuals** regarding the use of the compiler, top-level, debuggers, environment, module system, etc.

The Classical Top-Level Shell

- Modern Logic Programming Systems offer several ways of writing, compiling, debugging, and running programs.
- Classical model:
  - ◇ User interacts directly with a top-level shell (includes compiler/interpreter, debugger, etc.).
  - ◇ A prototypical session with a classical Prolog-style, text-based, top-level shell (details are those of the Ciao system, user input in **bold**):

[37]> **ciao**	Invoke the system
Ciao X.YY ...	
?- **use_module('*file*.pl').**	Load your program file
yes	
?- ***query_containing_variable_X*.**	Query the program
X = *binding_for_X* **;**	See one answer, ask for another using "**;**"
X = *another_binding_for_X* <**enter**>	Discard rest of answers using <**enter**>
?- ***another query.***	Submit another query
?-	
?- **halt.**	End the session, also with ˆ**D**

Program Load in the Top-Level Shell

- To load a program into the top level use the same commands as when using code inside a module:
  - `use_module/1` – for loading *modules*.
  - `use_package/1` – for loading *packages* (see later).
  - `ensure_loaded/1` – for loading *user files* (discouraged, modules preferred).

  Note: it is recommended to always use a module declaration, even if empty:

  ```
  :- module(_,_).
  ```

  since it allows the compiler to detect many more errors.

- In summary, the top-level behaves essentially the same as a module.
- Program load can also be *done automatically within one of the graphical environments*:
  - Open the source file.
  - Edit it (with syntax coloring, etc.).
  - Load it by typing `C-c l` or using menus.
  - Interact with it in top level.
  - Use the debugger, documenter, tests, etc.

Top Level Interaction Example

- File `lmember.pl`:

```
:- module(lmember,[lmember/2]).

lmember(X, [X|_Rest]).
lmember(X, [_|Rest]):- lmember(X, Rest).
```

- Load into top level and run (issue queries):

```
?- use_module(lmember).
yes
?- lmember(c,[a,b,c]).
yes
?- lmember(d,[a,b,c]).
no
?- lmember(X,[a,b,c]).
X = a ?  ;
X = b ?  (intro)
yes
```

Defining a module, its exports, and packages to load

- `:- module(<module_name>, <list_of_exports>, <list_of_packages>).`
  Declares a module of name *module_name*, which exports *list_of_exports* and loads *list_of_packages* (packages are syntactic and semantic extensions).
- Example: `:- module(lists, [list/1, member/2], [functions]).`
- Examples of some standard uses and packages:
  - ◇ `:- module(<module_name>, [<exports>], []).`
    ⇒ Module has access to the basic language (no packages loaded).
  - ◇ `:- module(<module_name>, [<exports>], [<packages>]).`
    ⇒ Module has access to the kernel language + some packages.
  - ◇ `:- module(<module_name>,[<exports>], [fsyntax]).`
    ⇒ Adds support for functional syntax.
  - ◇ `:- module(<module_name>,[<exports>],[assertions,fsyntax]).`
    ⇒ Adds support for assertions (types, modes, etc.) and func. syntax.

Pure modules and search rule selection

- For writing *pure logic programs*, files should start with the following line:
  - `:- module(_,_,[sr/bfall]).`
    To execute in *breadth-first* mode.
  - `:- module(_,_,[]).`
    To execute in *depth-first* mode.
  - Also, the package `pure` can be added so that impure built-ins are not accessible to the code in that module.

(ISO-)Prolog modules

- Strict (ISO-)Prolog:
  - `:- module(module_name, [exports], [iso_strict]).`

    ⇒ module has access to the ISO Prolog predefined predicates.

  - `:- module(module_name,[exports], [classic]).`

    ⇒ "Classic" Prolog module
    (ISO + all other predicates that traditional Prologs offer as "built-ins").

  - Special form:
    `:- module(module_name, [exports]).`
    Equivalent to:
    `:- module(module_name, [exports], [classic]).`

    ⇒ Provides compatibility with traditional Prolog systems.

Defining modules and exports (Contd.)

- Useful shortcuts:
  - `:- module(_,` *list_of_exports*`).`

    If given as "_" module name taken from file name (default).
    Example: `:- module(_, [list/1, member/2]).` and file is `lists.pl`
    ⇒ module name is `lists`.
  - `:- module(_,_).`

    If *list_of_exports* is "_" all predicates are exported (very useful for prototyping).
- "User" files:
  - Traditional name for files including predicates but no module declaration.
  - Provided for backwards compatibility with non-modular Prolog systems.
  - Not recommended: they are *problematic* (and, essentially, deprecated).
  - Much better alternative: use `:- module(_, _).` at top of file.
    * As easy to use for quick prototyping as "user" files.
    * Many advantages: *much* better error detection, compilation, optimization, ...

Importing from another module

- Importing / using predicates from other modules into a given module:
  - `:- use_module(filename).`

    Imports all predicates that module *filename* exports.
  - `:- use_module(filename, list_of_imports).`

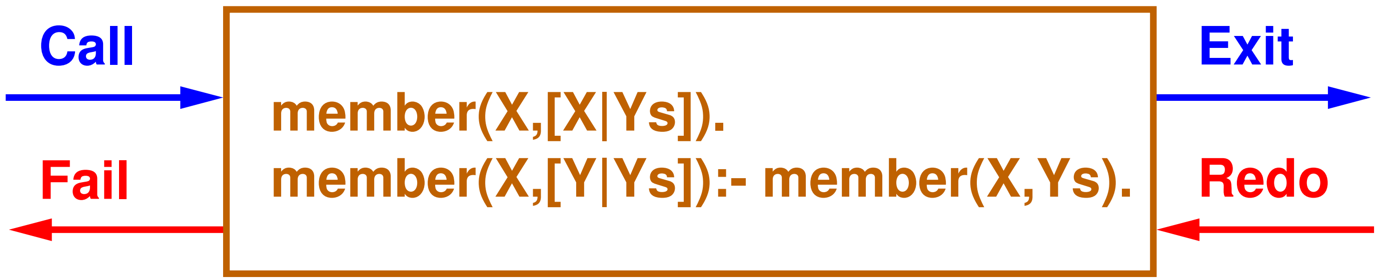
    Imports predicates in *list_of_imports* from module *filename*.
  - `:- ensure_loaded(filename).` —for loading user files (deprecated).
- When importing predicates with the same name from different modules, module name is used to disambiguate:

```
:- module(main,[main/0]).
:- use_module(lists,[member/2]).
:- use_module(trees,[member/2]).

main :-
     produce_list(L),
     lists:member(X,L),
     ...
```

The Debugger: Tracing an Execution with The "Byrd Box Model"

- Procedures (predicates) seen as "black boxes" in the usual way.
- However, simple call/return not enough, due to backtracking.
- Instead, "4-port box view" of predicates:



- Principal events in Prolog execution (*goal* is a unique, run-time call to a predicate):
  - ◇ *Call* goal: Start to execute goal.
  - ◇ *Exit* goal: Succeed in producing a solution to goal.
  - ◇ *Redo* goal: Attempt to find an alternative solution to goal (sol$_{i+1}$ if sol$_i$ was the one computed in the previous *exit*).
  - ◇ *Fail* goal: exit with fail, if no further solutions to goal found (i.e., sol$_i$ was the last one, and the goal which called this box is entered via the "redo" port).

Debugging Example

```
Ciao 1.XX ...
?- use_module('/home/logalg/public_html/slides/lmember.pl').
yes
?- debug_module(lmember).
{Consider reloading module lmember}
{Modules selected for debugging: [lmember]}
{No module is selected for source debugging}
yes
?- trace.
{The debugger will first creep -- showing everything (trace)}
yes
{trace}
?-
```

- Much easier: open the file in Emacs, VSC, or other supported IDE and type push the debug icon (or use the CiaoDbg menu, type `C-c d`, etc.).
- This loads the current module in *source debug* mode, i.e., the debugger traces the position in the source file.

Debugging Example (Contd.)

```
?- lmember(X,[a,b]).
   1  1  Call: lmember:lmember(_282,[a,b]) ?
   1  1  Exit: lmember:lmember(a,[a,b]) ?
X = a ? ;
   1  1  Redo: lmember:lmember(a,[a,b]) ?
   2  2  Call: lmember:lmember(_282,[b]) ?
   2  2  Exit: lmember:lmember(b,[b]) ?
   1  1  Exit: lmember:lmember(b,[a,b]) ?
X = b ? ;
   1  1  Redo: lmember:lmember(b,[a,b]) ?
   2  2  Redo: lmember:lmember(b,[b]) ?
   3  3  Call: lmember:lmember(_282,[]) ?
   3  3  Fail: lmember:lmember(_282,[]) ?
   2  2  Fail: lmember:lmember(_282,[b]) ?
   1  1  Fail: lmember:lmember(_282,[a,b]) ?
no
```

Options During Tracing

`h`	Get help — gives this list (possibly with more options)
`c`	Creep forward to the next event Advances execution until next call/exit/redo/fail
`intro`	(same as above)
`s`	Skip over the details of executing the current goal Resume tracing when execution returns from current goal
`l`	Leap forward to next “spypoint” (see below)
`f`	Make the current goal fail This forces the last pending branch to be taken
`a`	Abort the current execution
`r`	Redo the current goal execution very useful after a failure or exit with weird result
`b`	Break — invoke a recursive top level

- Many other options in modern Prolog systems.
- Also, graphical and source debuggers available in these systems.

Spypoints (and breakpoints)

- `?- spy foo/3.`

  Place a spypoint on predicate `foo` of arity 3 – always trace events involving this predicate.

- `?- nospy foo/3.`

  Remove the spypoint in `foo/3`.

- `?- nospyall.`

  Remove all spypoints.

- In many systems (e.g., Ciao) also *breakpoints* can be set at particular program points within the graphical environment.

Debugger Modes

- `?- debug.`
  Turns debugger on. It will first leap, stopping at spypoints and breakpoints.
- `?- nodebug.`
  Turns debugger off.
- `?- trace.`
  The debugger will first creep, as if at a spypoint.
- `?- notrace.`
  The debugger will leap, stopping at spypoints and breakpoints.

Creating Executables

- You can use:
  - The standalone compiler. E.g., in a shell:
    `ciaoc foo.pl`
    creates an executable `foo`.
  - Can also be done from the top level:
    `?- make_exec('foo.pl',foo).`
- The executables generated by Ciao's compiler can be:
  - eager dynamic load,
  - lazy dynamic load,
  - static (portable, architecture-independent –needs minimal Ciao installed),
  - fully static/standalone (fully portable, but architecture-dependent).