Logic Programming with PROFETA

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Programmazione Sistemi Robotici
PROFETA (Python RObotic Framework for dEsining sTrAtegies) is a Python tool for programming autonomous systems (agents or robots) using a declarative approach.

The aim is to have a single environment to implement the software of an autonomous robot.

It provides an “all-in-one” environment supporting both imperative (algorithmical part) and declarative (behavioural part) programming models.

It can be downloaded from: http://github.com/corradosantoro/profeta
PROFETA Basics

- PROFETA is inspired by AgentSpeak(L), a kernel agent language based on the belief-desire-intention (BDI) paradigm.
- Its syntax is logic/declarative with some similarities with Prolog.
- Concepts:
  - Beliefs
  - Goals
  - Actions
  - Plans
Beliefs are used to represent agent’s knowledge (agent status, data, environment status, etc.)

Beliefs can be added to or removed from a Knowledge Base (KB) (provided by PROFETA)

The KB can be queried to check the presence of certain beliefs and behave accordingly

Beliefs are syntactically expressed by atomic formulae with ground terms:

- position(150,60)
- block(“red”)
- stack(“cube”,“pyramid”)
**Goals** are used to represent the *motivational state* of the agent, i.e. what the agent wants to do.

Actions needed to achieve a certain goal are specified in a *goal plan* of the behaviour (see below).

A goal can be achieved by “calling it”, in a way similar to a procedure call.

Goals are syntactically expressed by atomic formulae with ground terms or free variables:

- `pick_block("red")`
- `pick_block("X")`
**PROFETA Actions**

- **Actions** are used to represent the *execution units*, driving an agent to achieve their goals.
- Actions contain the specific code (written in Python) to let the robot concretely perform “that thing” on the environment.
- Actions may **fail** and may be **asynchronous**.
- Actions to execute are specified in the behaviour **plans** (see below).
- Actions are syntactically expressed by **atomic formulae** with ground terms or bound variables:
  - `go_to(1500, 120)`
  - `grip_open()`
A PROFETA behaviour is a set of **reactive plans** in the form **Event-Condition-Actions**:

- **The Event** is a predicate that triggers the plan:
  - **belief assert**
  - **belief retract**
  - **goal achievement**
  - **goal failure**

- **Condition** is a guard which needs to be true in order to trigger the plan.
- **Actions** is a list of “things to do” when the plan is triggered:
# import libraries
from profeta.lib import *
from profeta.main import *

class say_hello(Goal):
    pass

# instantiate the engine
PROFETA.start()

# define a goal plan
say_hello() >> [ show_line("hello world from PROFETA") ]

# run the engine shell
PROFETA.run_shell(globals())
The plan is triggered when a belief `number(...)` is asserted.

- In this case, variable `X` will be bound to the parameter of the belief and will be printed in the message.
- Variables are `local` of the plan.
from profeta.lib import *
from profeta.main import *

class number(Belief):
    pass

# instantiate the engine
PROFETA.start()

# define an event plan
+number("X") >> [ show_line("yeah! Now I know the number", "X")]

# run the engine shell
PROFETA.run_shell(globals())

- In PROFETA, strings starting with uppercase represents variables
Graduated Students: A more “rational” Example

- We want to represent a world in which we have some students that, sooner or later, become graduated.
- When a student become graduated, s/he is no more a “student”
- We use two beliefs:
  - student(X) to represent the fact that “X” is a student
  - graduated(X) to represent the fact that “X” is graduated
- We have the following “knowledge rules”:
  - “X”, to be graduated(X), must be (before) student(X)
  - When “X” becomes graduated(X) it is no more a student(X)

```python
class student(Belief):
    pass

class graduated(Belief):
    pass

+graduated("X") / student("X") >> [ -student("X"),
                           show_line("yeah ", "X", "is now graduated!") ]
+graduated("X") >> [ show_line("X", "is not a student"),
                     -graduated("X") ]
```
Graduated Students: A more “rational” Example

```python
class student(Belief):
    pass

class graduated(Belief):
    pass

+graduated("X") / student("X") >> [ -student("X"),
    show_line("yeah ", "X", "is now graduated!") ]
+graduated("X") >> [ show_line("X", "is not a student"),
    -graduated("X") ]
```

- Both plans have the same **triggering event**: +graduated("X")
- These plans represent a **group of plans** since they share the same triggering event
- **Only a plan** in a group can be executed
- Selection is made on the basis of **writing order**: the first plan that matches the condition is executed
Here `+factorial(...)` is used only to generate an event but not to represent a knowledge.

For this reason `factorial(...)` is defined as a Reactor, i.e. a belief that does not populate the knowledge base but can trigger plans.

To perform an iteration, implementation exploits “plan retriggering”, a technique which is similar to recursion.

The recursion exploits an additional belief variable "Acc" (stands for “accumulator”) which stores the partial result of the factorial.
```python
class factorial(Goal):
    pass

factorial(0, "Acc") >> [ show_line("factorial is ", "Acc") ]
factorial("N", "Acc") >> [ "Acc = Acc * N", "N = N - 1", factorial("N", "Acc") ]
factorial("N") >> [ factorial("N", 1) ]
```

- The same result can be achieved by using a **Goal** instead of a Reactor
- A Goal is similar to a “procedure call” so, in this case, is more appropriate than using the Reactor
Let's sum $n$ numbers each represented by belief $\text{number}(X)$.

We use a goal $\text{sum_all(”N”)}$ that and a plan that “retrieves” a number from the KB and sums it to $N$.

Each number processed is then removed from the knowledge base.

```python
class sum_all(Goal):
    pass

class number(Belief):
    pass

sum_all("N") / number("X") >> [ "N = N + X", -number("X"),
                               sum_all("N") ]

sum_all("N") >> [ show_line("the sum is", "N") ]

sum_all() >> [ sum_all(0) ]
```
Plan

\[
\text{sum\_all}("N") \ / \ \text{number}("X") \ >> \ [ \ "N = N + X", \ -\text{number}("X"), \\
\quad \text{sum\_all}("N") ]
\]

contains a condition

- It can be triggered if a belief \text{number} is present in the knowledge base
- Variable \text{X}, since it is not used before, is a free variable and can thus be bound to any value
- The result is a match to any belief \text{number}
Generative Reactive Programming: the Sieve of Eratosthene

To implement the sieve of Eratosthene we consider numbers each one represented by belief `number(X)`

A plan is used to find pairs `(number(X), number(Y))` and remove the former belief if `X` is a multiple of `Y`

Here we use a condition made of an AND-composite predicate that also uses lambdas to implement boolean conditions

```python
from profeta.lib import *
from profeta.main import *

class number(Belief):
    pass

+number("X") / ( number("Y") &
    (lambda: X != Y) &
    (lambda: (X % Y) == 0) ) >> [ -number("X") ]

# populate the KB
for i in range(2,100):
    PROFETA.assert_belief(number(i))
```
Generative Reactive Programming: the Sieve of Eratosthene

Plan

\[ +\text{number}("X") \div (\text{number}("Y") \&
(\lambda: X \neq Y) \&
(\lambda: (X \% Y) = 0) ) \gg [ -\text{number}("X") ] \]

is triggered when a \text{number}(X) is asserted

The condition searches for any another \text{number}(Y), but the other checks ensure that

1. \( X \) and \( Y \) are different (i.e. the beliefs do not refer to the same number)
2. \( X \) is a multiple of \( Y \) (their “module” operation results to zero)

If all checks are true, \text{number}(X) (the multiple) is removed from the KB
Case Study: SHRDLU
The world of SHRDLU

- **SHRDLU** is one of the first artificial intelligence programs (1968-1970) supporting **reasoning/planning** and natural language processing.
- It is based on a (virtual) environment composed of some “blocks” with different shapes and colors (cubes, pyramids, prisms, cylinders, etc.).
- The program can understand commands like “Pick up a big red block” or “Grasp the pyramid” and behave accordingly.
- The name **SHRDLU** comes from the sequence **ETAOIN SHRDLU** (why?) which is the same sequence of the keys of the Linotype (based on the frequency of letters in the English language).
The Linotype and the SHRDLU sequence

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Logic Programming with PROFETA
Let’s implement a small version of SHRDLU with PROFETA (see the code in file “SHRDLU.py”).

Our world is based on 3D objects: cube, cylinder, prism.

These objects are placed on a table and they can be picked up by a robot.

On the table, objects may be stacked, one on the top of another, in order to form a tower.

An object can be picked only if it is free (it has no other objects on the top).
BELIEFS:
- \( \text{obj}(X) \), represents the presence of block \( X \) on the table
- \( \text{owned}(X) \), represents the fact that the block \( X \) is owned (picked) by the robot
- \( \text{upon}(X, Y) \), block \( X \) is placed upon block \( Y \)

GOALS:
- \( \text{pick}(X) \), request to pick block \( X \), if possible
- \( \text{put}(X) \), request to put block \( X \) on the table
- \( \text{put}(X, Y) \), request to put block \( X \) upon block \( Y \)
Object X is on the table, but another object Y is upon it ⇒ X cannot be picked

\[
pick("X") / (obj("X") & upon("Y", "X")) >> \[ show\_line("cannot pick", "X", "since it is under the", "Y") ]
\]

If previous condition is false and object X is on the table and it is on the top of object Y ⇒ X can be picked (update beliefs accordingly)

\[
pick("X") / (obj("X") & upon("X", "Y")) >> \[ show\_line("X", "picked"), -obj("X"), -upon("X", "Y"), +owned("X") ]
\]
If previous condition is false and object X is on the table (no other objects on the top of it) ⇒ X can be picked (update beliefs)

\[
\text{pick("X") / obj("X") >> [ show_line("X", "picked"), } \\
\text{-obj("X"), +owned("X") ]}
\]

If previous condition is false and object X is owned by the robot ⇒ X cannot be picked

\[
\text{pick("X") / owned("X") >> [ show("you’ve still got", "X") ]}
\]

If all previous conditions are false the last plan is triggered ⇒ it means that object X does not exist

\[
\text{pick("X") >> [ show_line("cannot pick", "X", } \\
\text{"since it is not present") ]}
\]
Summary of the plans for object picking:

- $\text{pick}("X") / (\text{obj}("X") \& \text{upon}("Y", "X")) >> \ [ \text{show}\_\text{line}(\"cannot pick\", "X", \"since it is under the\", "Y\") ]$

- $\text{pick}("X") / (\text{obj}("X") \& \text{upon}("X", "Y")) >> \ [ \text{show}\_\text{line}("X", \"picked\"), \neg\text{obj}("X"), \neg\text{upon}("X", "Y"), +\text{owned}("X") ]$

- $\text{pick}("X") / \text{obj}("X") >> \ [ \text{show}\_\text{line}("X", \"picked\"), \neg\text{obj}("X"), +\text{owned}("X") ]$

- $\text{pick}("X") / \text{owned}("X") >> \ [ \text{show}(\"you’ve still got\", "X") ]$

- $\text{pick}("X") >> \ [ \text{show}\_\text{line}(\"cannot pick\", "X", \"since it is not present\") ]$
Object X is owned $\Rightarrow$ put X on the table

```
put("X") / owned("X") >> \
  [ show_line("X", "is now on the table"),
    -owned("X"), +obj("X") ]
```

Object X is already on the table $\Rightarrow$ nothing to do

```
put("X") / obj("X") >> \
  [ show_line("X", "is already on the table") ]
```

Object X is neither held nor on the table $\Rightarrow$ the object does not exist, nothing to do

```
put("X") >> [ show_line("X", "does not exist") ]
```
We want to put object X on the top of object Y:

- Object X is owned, object Y is on the table but Y has another object Z on the top of it ⇒ we cannot do the job

```
put("X", "Y") / (owned("X") & obj("Y") & upon("Z", "Y") ) \\
>> [ show_line("Y", "has", "Z", "on its top") ]
```

- Object X is owned, object Y is on the table but, since here the previous condition is false, Y is free ⇒ we can put X upon Y

```
put("X", "Y") / (owned("X") & obj("Y") ) >> \\
[ -owned("X"), +obj("X"), +upon("X", "Y"), \\
  show_line("done") ]
```
Summary of the plans for object release:

\[
\begin{align*}
\text{pick}("X") & \land \text{obj}("X") \land \text{upon}("Y", "X")] \\
& \quad \Rightarrow \quad [ \text{show\_line}("\text{cannot pick", "X", "since it is under the", "Y")}] \\
\text{pick}("X") & \land \text{obj}("X") \land \text{upon}("X", "Y")] \\
& \quad \Rightarrow \quad [\text{show\_line}("X", "picked"), \\
& \quad \quad \quad \text{-obj}("X"), \text{-upon}("X", "Y"), \text{+owned}("X")] \\
\text{pick}("X") & \land \text{obj}("X") \\
& \quad \Rightarrow \quad [\text{show\_line}("X", "picked"), \\
& \quad \quad \quad \text{-obj}("X"), \text{+owned}("X")] \\
\text{pick}("X") & \land \text{owned}("X") \\
& \quad \Rightarrow \quad [\text{show}("you’ve still got", "X")] \\
\text{pick}("X") & \quad \Rightarrow \quad [\text{show\_line}("\text{cannot pick", "X", \\
& \quad \quad \quad \text{"since it is not present")}] \\
\end{align*}
\]
Let’s see a run of SHRDLU
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