Intelligent Systems: Reasoning and Recognition

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Rule based programming - Introduction to CLIPS 6.0

Production Systems

Three techniques are commonly used to represent knowledge:

Rules
Schema systems
Logic

Many modern AI programming environment combine all three.

Rules are typically expressed as:

if <CONDITION> then <ACTION>

Rules are often used to program procedural or reactive intelligence.

Rule based programming languages take their inspiration from the observation of conditioned reflexes in animals and humans.

Conditioned Reflexes are trained associations (PAVLOV)

Condition ⇒ Reaction

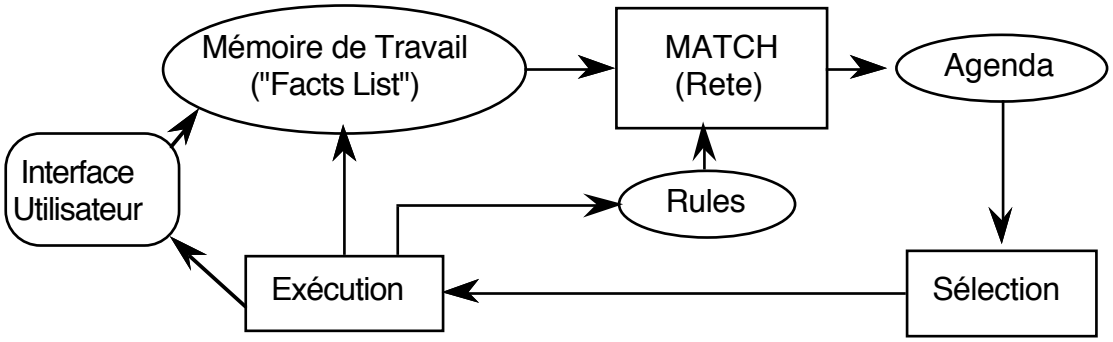
A reaction can be the assertion of a fact or a physical action.

The association of facts and rules poses an important problem for rule based programming environments. If the rules can contain variables, then the algorithmic complexity is exponential in the number of conditions.

In this lesson we will learn of a "fast" algorithm for matching rules to Facts: RETE.

In 1975, Alan Newell at CMU took on a doctoral student named Laney Forgy. Newell asked Forgy to create a programming environment for rule based programming. The result was a system named "OPS" (Operational Production System")

Production System architecture



The system implements an "inference engine" that operates as a 3 phase cycle:

The cycle is called the "recognize act" cycle.
The phases are:

MATCH: match facts in Short Term memory to rules
SELECT: Select the correspondence of facts and rules to execute
EXECUTE: Execute the action par of the rule.

Newell and Forgy soon discovered that in a such a system, adding variables to the rules greatly enhances the expressive power, but at the same time causes a problem of algorithmic complexity in the matching of rules to facts. Newell asked Forgy to develop a fast algorithm for matching rules to Facts. The result is the RETE algorithm.

In this architecture, each fact is labeled with an index. In each cycle, the CONDITION part of rules are matched to the facts. The association of facts and rules are stored in an agenda. One of the associations is then selected for execution.

The list of associations of facts and rules are stored in an agenda. One of the associations is selected for execution.

There are several different models for how to sort the agenda. The most popular is to use a stack "Last In First Out" or LIFO.

Rule based programming languages:

OPS-5 ('78) => ART ('80) => CLIPS ('85) => CLIPS 6 ('94)

The OPS system was used to construct a very successful expert system for configuring VAX computers (R1). R1 gained several hundred million dollars for Digital Equipment Corporation from 1980 to 1985.

CLIPS : "C Language Integrated Production System"

The OPS system was commercialized by DEC, but also by Teknowledge under the name "ART" Automated Reasoning Tool. NASA selected ART as its standard. Unfortunately ART was built in the LISP language and was very expensive.
(50 K$ for the license, 50 K$ for the LISP machine).
In 1985, NASA engineers reprogrammed ART in C. The result was called CLIPS.

The origin of CLIPS is a C language version of the ART system (Automated Reasoning Tool) programmed by NASA engineers.

OPS, ART and CLIPS all share the same architecture, and use the RETE algorithm.

As a public organization, NASA distributed CLIPS for free (Before GNU and ShareWare)

Successive versions of CLIPs have been distributed and a substantial user community has emerged. We will use a version, CLIPS 6.0, that is programmed using object oriented programming. This version integrates many different knowledge representation styles, including Rules, Schema, and a logic based Truth Maintenance system.

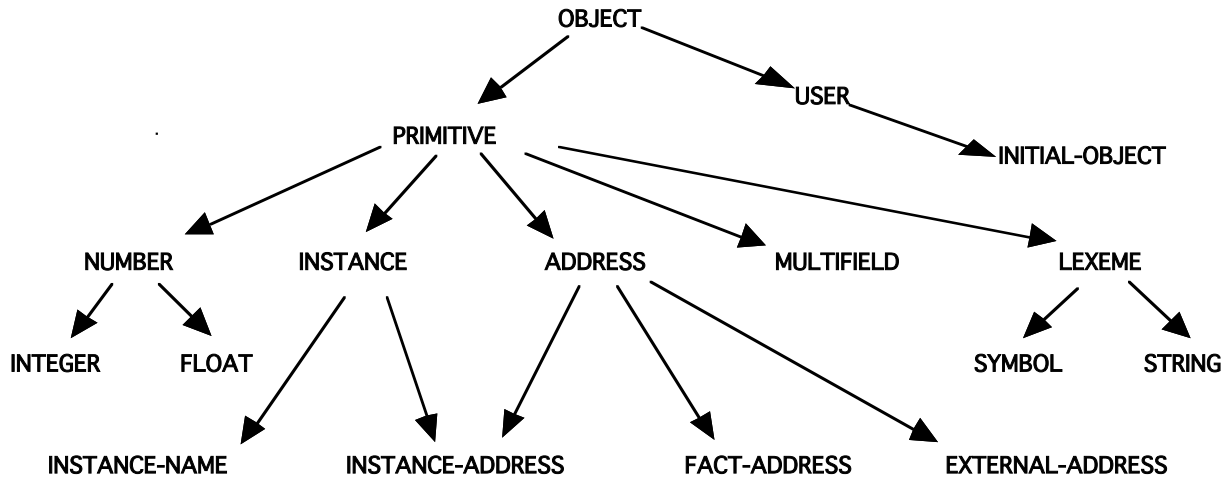
For NASA, CLIPS is used to construct Expert Systems for
1) Process Control
2) On-Board Error Diagnostic
3) Mission Planning
4) Logistics Planning.

The Facts List

The working memory of CLIPS is called the "Facts List".
A Fact can represent:

- A list of items (PRIMITIVES including symbols, strings, integers or floats)
- A template composed of a "name" and a list of "attribute-value" pairs.
- An object from the CLIPS object oriented system.

CLIPS' working memory is represented as a list of facts.
Fact are a list or structure or items (or an object).
Items belong to a hierarchy of 13 primitive types.



It is also possible to define new types. Version 6.0 of CLIPS contains an object oriented environment named COOL. ("C-Language Object Oriented Language").
User defined types belong to the class COOL class USER

In later lessons we will use the COOL. For now, we will work with lists and structures.

Facts, in CLIPS, are created and destroyed by the commands:

ASSERT: (ASSERT <<FACT>>)
RETRACT, (RETRACT <<INDEX>>)

(CLEAR) - Empties the working memory
(RESET) - Resets the entire system to empty.

Typing (CLEAR) creates an "initial fact" with index 0.

f-0 (initial-fact)

There are 5 keywords that cannot be used in the first field in a fact:
Test, and, or, not, declare.

Each fact is identified by a unique "index". Indices are allocated in order. They are fundamental to the logic of CLIPS.

(assert (a b c))
ATTN (assert (1 2 3)) will generate an error. The first item must be a symbol

Deftemplates

A template is a set of "attribute - value" pairs. The attribute name are used as an index into the template. Such structures are defined with deftemplate.

A template makes it possible to manipulate attributes of a fact without having to scan through a list. Attributes are called "slots" in clips.

Example:

```
(deftemplate person         ;  A template for a person
   "template for a person" ;  Optional Comment
   (slot name               ; Name of a person
      (default "John Doe"))   ; Default name
   (slot age             ; age of the person
      (type INTEGER))  ; default will be 0
)
```

Instances of templates are created by (assert).

```
(assert (person))
(assert (person (name "joe")))
(assert (person (name "jim") (age 39)))
```

A number of commands exist inspecting templates

(list-deftemplates)
(ppdeftemplate <template-name>)
(undeftemplate <template-name>)

examples:

```
CLIPS> (list-deftemplates)
initial-fact
person
For a total of 2 deftemplates.
CLIPS> (ppdeftemplate person)
(deftemplate MAIN::person "template for a person"
   (slot name (default "John Doe"))
   (slot age (type INTEGER)))
CLIPS>
```

We can define types and default values for slots.
We can also define a list of allowed symbols for a slot value.

example :

```
(deftemplate person        ;  A template for a person
"template for a person" ;  Optional Comment
   (slot name           ; Names of a person
   (type STRING)
(default "Pierre Dupont")) ; Default name
   (slot age            ; age of the person
      (type INTEGER)    ; default will be 0
      (range 0 120))   ; Possible ages
 (slot Profession      ;
      (type SYMBOL)
      (allowed-values  artist  engineer  salesman  manager
         other none)
      (default none)
 )
)
```

For numbers we can define a range

(slot age
(type NUMBER)
(range 0 120))

deffacts

A predefined list of facts can be created by the expression "deffacts".

(deffacts <NOM> ["<comment>"]
[(<<FAIT-1>>) (<<FAIT-2>>) ... (<<FAIT-N>>))

the command (reset) will empty the facts list and create an "initial-fact" and to create the list of default facts.

examples :

```
(deftemplate place
   (slot name (type SYMBOL) (default NIL))
   (slot x (type NUMBER) (default -1))
   (slot y (type NUMBER)(default -1))
   (multislot neighbors (default NIL))
)

(deffacts network-of-places
   (place (name A) (x 0) (y 0) (neighbors B C))
   (place (name B) (x 0) (y 1) (neighbors A D))
   (place (name C) (x 1) (y 0) (neighbors A I))
)

CLIPS> (deffacts network-of-places
   (place (name A) (x 0) (y 0) (neighbors B C))
   (place (name B) (x 0) (y 1) (neighbors A D))
   (place (name C) (x 1) (y 0) (neighbors A I))
)
CLIPS> (reset)
CLIPS> (facts)
f-0     (initial-fact)
f-1     (place (name A) (x 0) (y 0) (neighbors B C))
f-2     (place (name B) (x 0) (y 1) (neighbors A D))
f-3     (place (name C) (x 1) (y 0) (neighbors A I))
For a total of 4 facts.
```

Rules in CLIPS

CLIPS rules allow programming of reactive knowledge.
Rules are defined by the "defrule" command.

```
(defrule <rule-name> [<comment>]
     [<declaration>]                ; Rule Properties
     <conditional-element>*         ; Left-Hand Side (LHS)
=>
     <action>*)                     ; Right-Hand Side (RHS)
```

If the rule with the same name exists, it is replaced.
else the rule is created.

There is no limit to the number of conditions or actions (* means 0 or more).
Actions are executed sequentially.

Rules with no condition are activated by (Initial-Fact)

The syntax for condition elements is complex:

```
<conditional-element> ::= <pattern-CE> |
                          <assigned-pattern-CE> |
                          <not-CE> |
                          <and-CE> |
                          <or-CE> |
                          <logical-CE> |
                          <test-CE>
```

A condition element (CE) can be a list or a template or user defined object.

List: (<constant-1> ... <constant-n>)
Deftemplate:

```
(<deftemplate-name> (<slot-name-1> <constant-1>)
                                   •
                                   •
                                   •
                    (<slot-name-n> <constant-n>))
```

A CE can contain constant values or variables.

Variables

Variables are represented by ?x
There are two sorts of variables in CLIPS:

Index Variables: are assigned the index of a fact that matches a CE.
Attribute Variables: Contain the value of a item that matched a CE.

Index Variables

Variable : ?x

Index variables are used to identify a fact that has matched a CE
This can be used to retract of modify the fact.

```
(defrule rule-A
   ?f <- (a)
=>
   (printout t "Retracting  " ?f  crlf)
   (retract ?f)
)

(deftemplate A (slot B (default 0)))

(defrule rule-A
   ?f <- (A (B 0))
=>
   (printout t "Changing  " ?f  crlf)
   (modify ?f (B 1))
)
```