Universidade do Minho
Escola de Engenharia
Departamento de Informática

Mestrado Integrado em Engenharia Informática
Mestrado em Engenharia Informática
Agentes Inteligentes
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ISLab
Synthetic Intelligence Lab

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- Centro ALGORITMI
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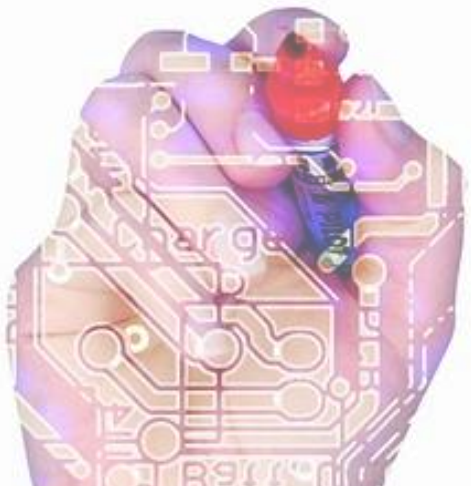
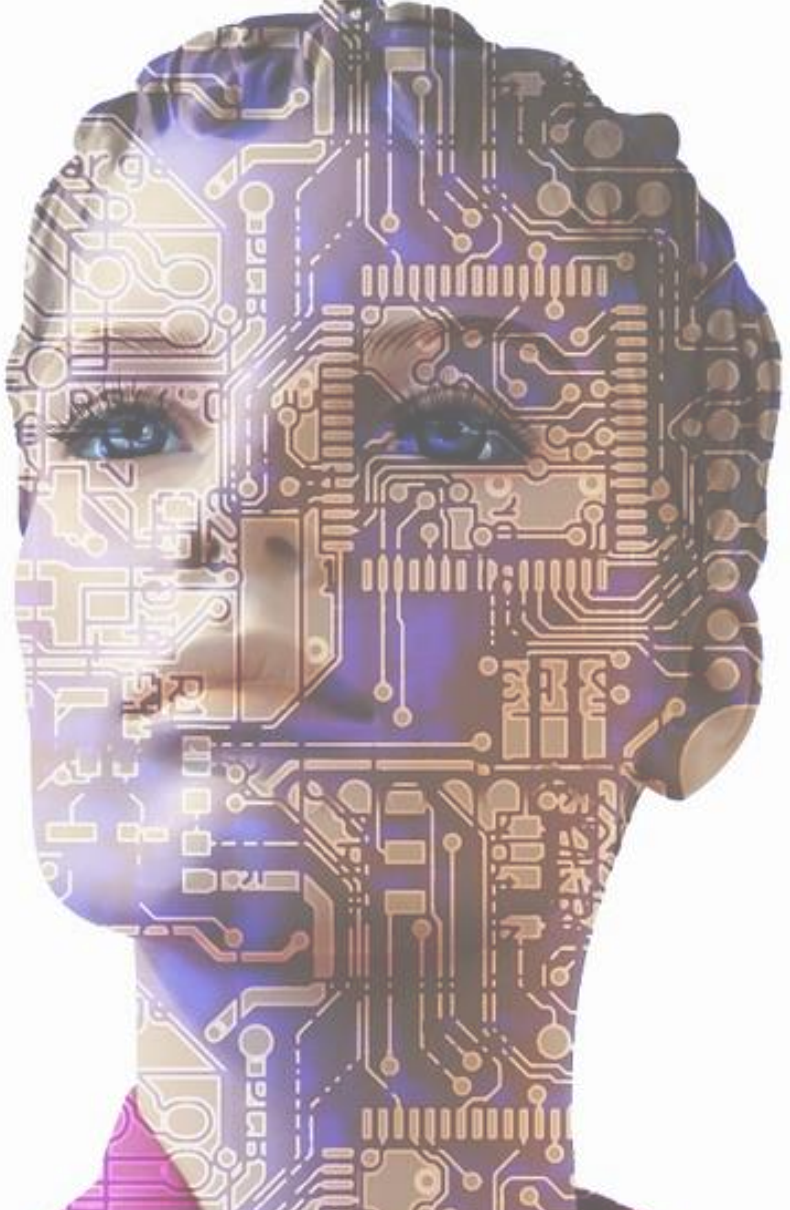
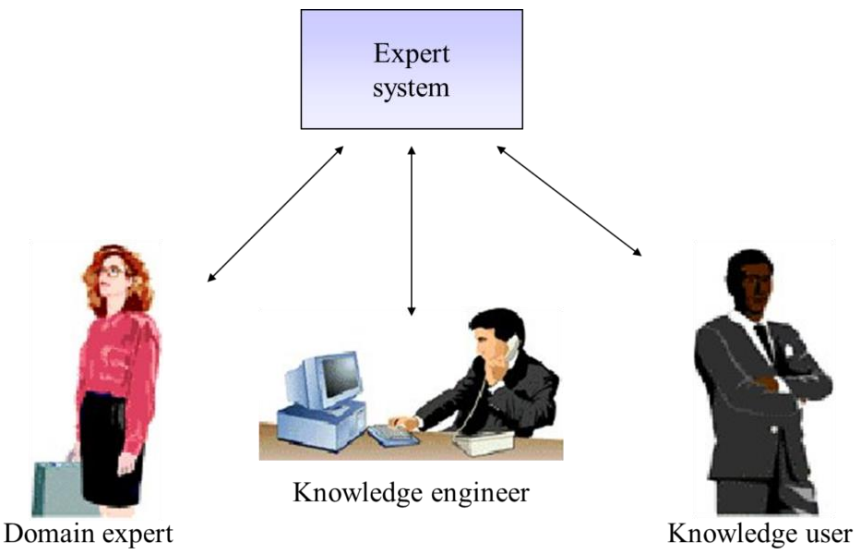
Rule-based System





Expert Systems

- An AI branch
- Simulation of human reasoning in a domain
- Rule-Based Expert Systems are the most used to:
  - Simulate human reasoning using heuristic knowledge
  - Problem data stored as facts
  - Reasoning based on rules of type *IF ... THEN ...*



Rule-based Systems

- Contain rules for a certain domain:
  - Knowledge not necessarily expert
  - Examples:
    - Definition of "business rules"
    - Decision components (e.g. in computational agents)

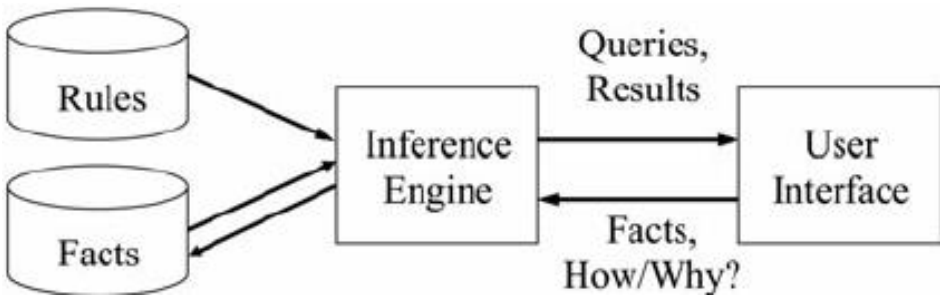
- Advantages:
  - Intuitive representation of knowledge
  - Division between knowledge and its application
  - Changes do not imply recompilation
- Paradigm of declarative programming:
  - Definition of independent rules
  - Non-sequential execution
  - Interpreter decides when to apply which rules

Rule-based Systems

- Chaining (execution) of rules:
  - **Backward-chaining**
    - Goal-driven: how to prove a goal?
    - Logical programming languages (e.g. Prolog)
  - **Forward-chaining**
    - Data-driven: what to do when a fact arises?
    - Production systems (e.g., CLIPS, JESS)

Rule-based Systems

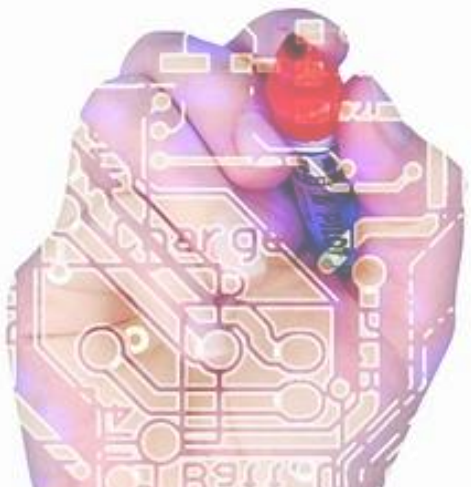
- Inference Engine: decides when to apply what rules; controls the activation and selection of rules
- Knowledge Base: saves the set of rules; rules follow the pattern *P1, ..., Pm → Q1, ..., Qn*, where if the premises/ conditions *P1, ..., Pm* are True, actions/conclusions *Q1, ..., Qn* will be executed
- Work Memory: saves facts and intermediate results that make up the current state of the problem; facts can be examined and modified by the rules

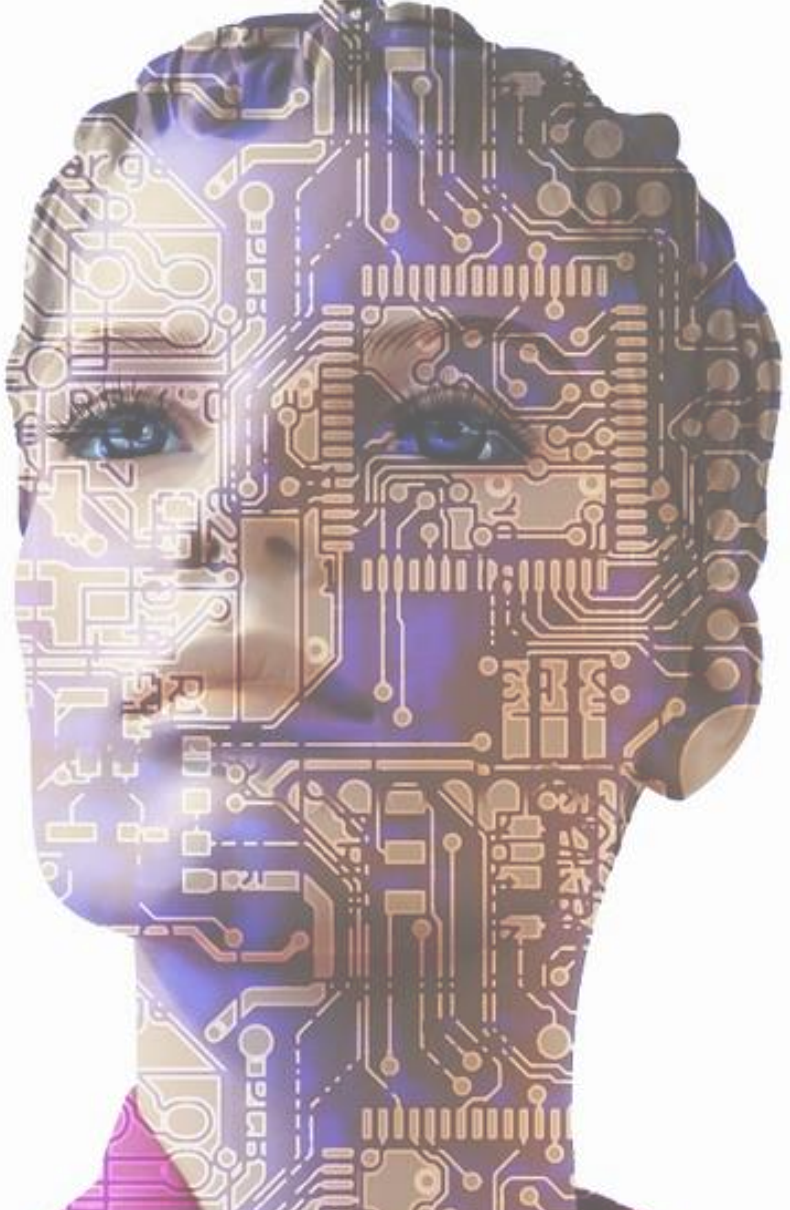


- The Inference Engine works in a cyclic way, decomposing into three phases:

1. Match Phase:
    - Groups the rules whose premises/conditions are satisfied by the work memory: the rules are instantiated with facts that make their premises true
    - Obtain the set of conflicts
2. Conflict Resolution Phase:
    - Selection of the rule to be performed, according to a strategy of conflict resolution (e.g. through priority)
3. Action Phase:
    - Sequential execution of the actions/conclusions presented in the selected rule
    - Actions / conclusions can modify Knowledge Base

JESS

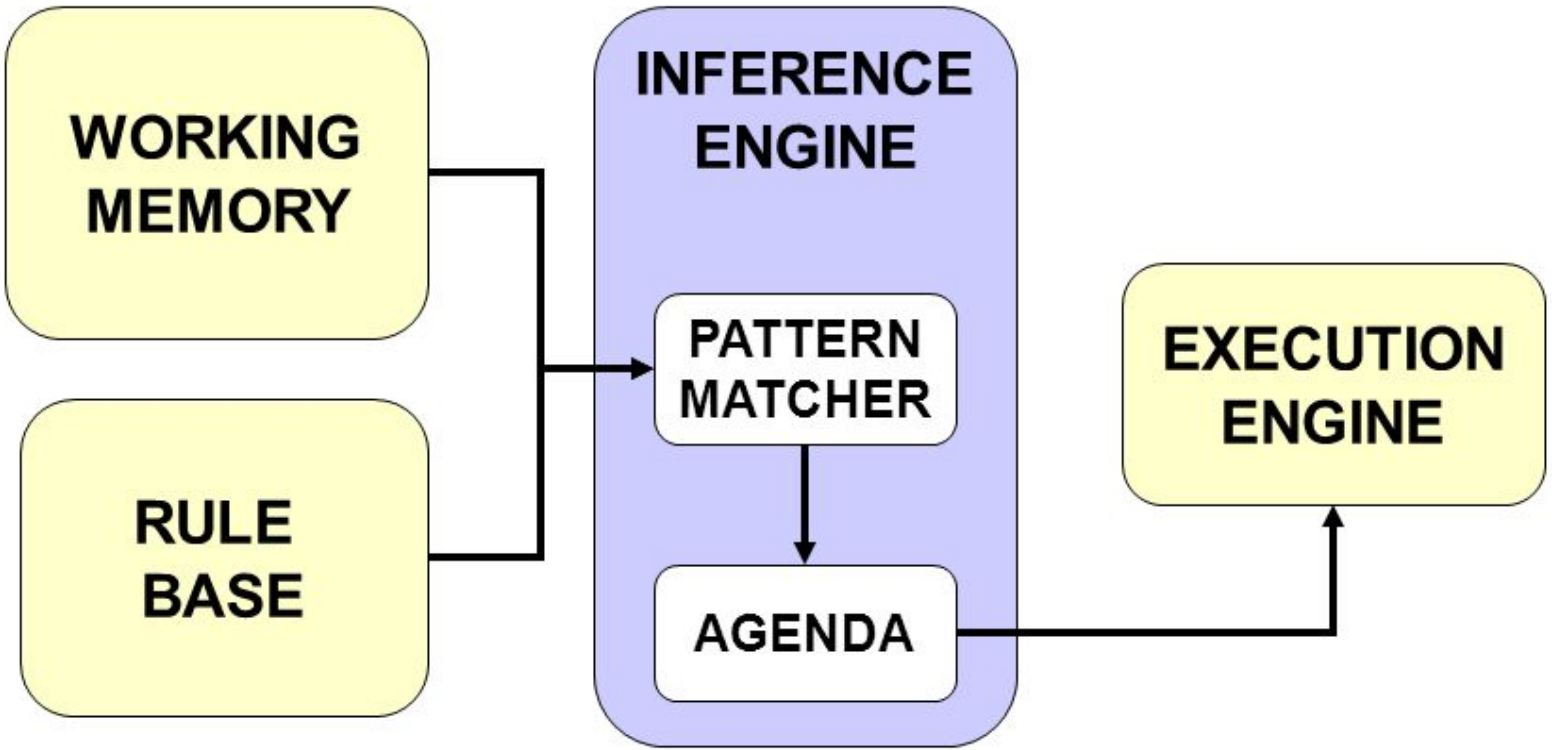




JESS

- A rule engine that very efficiently applies rules to date
- Inspired by the AI production rule language CLIPS (LISP-like syntax)
- Fully developed Java API for creating rule-based expert systems
- How does Jess work?
  - Jess matches facts in the fact base to rules in the rule base
  - The rules contain function calls that manipulate the fact base and/or other Java code
  - Jess uses the Rete algorithm to match patterns

JESS Architecture



JESS Syntax

- LISP-like syntax
- Can be used to script Java API: JAVA →JESS
- Can be used to access JavaBeans: JESS → JAVA
- Can create Java objects and access its methods from within Jess!

JESS Syntax - Basics

- Symbols:
  - identifiers: letters, digits and $*=+-/<>_?#.
  - Case-sensitive
  - Special Symbols: nil TRUE FALSE
- Numbers
- Strings: delimited by “”
- Lists:
  - Delimited by (e)
  - Contain zero or more symbols, numbers, strings, or other lists
  - Ex: *(+ 3 2) (a b c) ("Hello, World") ()*
    (deftemplate foo (slot bar))
  - The first element of the list is called the head of the list
- Comments:
  - All text after following a “;”
  - Comments code: / * ... * /

JESS Syntax - Functions

- Function calls (whether predefined or defined by the user) are lists
  - Notation prefix: the head of the list is the name of the function
  - Example:

```
Jess> (+ 2 3)
5
Jess> (+ (+ 2 3) (* 3 3))
14
Jess> (printout t "Answer is " 42 "!" crlf)
Answer is 42!
Jess> (batch examples/hello.clp)
```

JESS Syntax - Variables

- Identifiers that start with "?"
  - Can contain a symbol, number or string, or a list
  - Can be assigned a value through the function bind

    Jess> (bind? V "The value")

    Jess> (bind? Grocery-list (list eggs bread milk))
- Check the value of a variable

  Jess> (bind? A 123)

  Jess>? A

  123
- Variables are not declared before they are first used
  - Exception: you can create global variables, which are not destroyed during a *reset - defglobal*

JESS Syntax – Functions Definition

(*deffunction* <func-name> [<doc-comment>] (<parameter>*)
<expr>* [<return-specifier>])

- Example: *(deffunction max (?a ?b) (if (> ?a ?b) then (return ?a)*
  else (return ?b)))
- Flow control Funtions: *foreach*, *if*, *while*, ...
- Call:

  Jess> (printout t "Greater of 3 and 5 is " (max 3 5) "." crlf)
  Greater of 3 and 5 is 5.

JESS Syntax – Ordered Facts

- Ordered Facts:
  - lists in Jess
  - the head of the list serves as a sort of category
- Examples:

  (shopping-list eggs milk bread)
  (person "Bob Smith" Male 35)
  (father-of danielle ejfried)
- Assertion / retraction of facts: *assert / retract*
- Visualization of existing facts: *facts*
- Clear all facts: *clear*

JESS Syntax – Ordered Facts (Examples)

```
Jess> (reset)
TRUE
Jess> (assert (father-of danielle ejfried))
<Fact-1>
Jess> (facts)
f-0 (MAIN::initial-fact)
f-1 (MAIN::father-of danielle ejfried)
For a total of 2 facts in module MAIN.
Jess> (retract (fact-id 1))
TRUE
```

```
Jess> (facts)
f-0 (MAIN::initial-fact)
For a total of 1 facts in module MAIN.
```

Note: the fact (initial-fact) is created by the *reset* command

JESS Syntax – Unordered Facts

- Unordered Facts:
  - Allows to structure information

- Examples:

  (person (name "Bob Smith") (age 34) (gender Male))
  (automobile (make Ford) (model Explorer) (year 1999))

- Each fact has an associated *template* that defines its *slots*

```
(deftemplate <template-name> [extends <template-name>]
        [<doc-comment>]
        [(declare ...)]
        [(slot | multislot <slot-name>
                [(type <typespec>)
                [(default <value>)]
                ...
        )]*
)
```

JESS Syntax – Unordered Facts (Examples)

```
Jess> (deftemplate automobile
                    "A specific car."
                    (slot make)
                    (slot model)
                    (slot year (type INTEGER))
                    (slot color (default white)))
Jess> (assert (automobile (make Chrysler)
(model LeBaron) (year 1997)))
<Fact-0>
```

```
Jess> (facts)
f-0 (MAIN::automobile (make Chrysler) (model LeBaron)
(year 1997) (color white))
For a total of 1 facts in module MAIN.
```

JESS Syntax – Unordered Facts (Examples)

- *slot* that can hold multiple values: *multislot*

```
Jess> (deftemplate box (slot location)
(multislot contents))
TRUE
Jess> (bind ?id (assert (box (location kitchen)
(contents spatula sponge frying-pan))))
<Fact-1>
```

Note: the variable ?id was associated with the identifier of the fact

- Change the values of a slot: *modify*

- Extension of *deftemplate*:

```
Jess> (deftemplate used-auto extends automobile
(slot mileage) (slot blue-book-value)
(multislot owners))
TRUE
```

JESS Syntax - Deffacts

- Deffacts:
  - Allows to define grouped facts that are created when invoking the reset command
  - Example:

```
Jess> (deffacts my-facts "The documentation string"
(foo bar)(box (location garage)
(contents scissors paper rock))
(used-auto (year 1992) (make Saturn) (model SL1)
(mileage 120000) (blue-book-value 3500)
(owners ejfried)))
TRUE
Jess> (reset)
TRUE
Jess> (facts)
f-0 (MAIN::initial-fact)
f-1 (MAIN::foo bar)
f-2 (MAIN::box (location garage) (contents scissors
paper rock))
f-3 (MAIN::used-auto (make Saturn) (model SL1) (year
1992)
(color white) (mileage 120000)
(blue-book-value 3500) (owners ejfried))
For a total of 4 facts in module MAIN.
```

JESS Syntax – Shadow Facts

- Shadow Facts:
  - Unordered facts that map Java objects
  - A Java object can be placed in memory of work

- Shadow Facts templates:

(deftemplate <template-name>

(declare (from-class <class-name>)))

- Alternative:

(defclass <template-name> <class-name>)

The created template has slots corresponding to the JavaBeans properties of the class:

```
public class ExampleBean {
        private String name = "Bob";
        public String getName()
                { return name; }
        public void setName(String s)
                { name = s; }
}
```

JESS Syntax – Shadow Facts

- Java Object creation:

  (bind <var> (new <class-name>))

- Shadow Fact creation:

  (add <Java object>)

  - if it does not already exist, the template is created automatically

- Alternative:

  (definstance <template-name> <Java object>)

JESS Syntax – Shadow Facts (Examples)

- Template creation:

```
Jess> (defclass ExampleBean ExampleBean)
ExampleBean
Jess> (deftemplate ExampleBean)
        "(deftemplate MAIN::ExampleBean
        \"$JAVA-OBJECT$ ExampleBean\"
        (declare (from-class ExampleBean)))"
```

- Java object creation in Work Memory (shadow fact):

```
Jess> (bind ?x (new ExampleBean))
(Java-Object::ExampleBean
Jess> (add ?x)
<Fact-0>
Jess> (facts)
f-0 (MAIN::ExampleBean
(class <Java-Object:java.lang.Class>)
(name "Bob")
(OBJECT <Java-Object:ExampleBean>))
For a total of 1 facts in module MAIN.
```

JESS Syntax – Java Objects (Examples)

- Creation & use example of Hashtable:

```
Jess> (bind ?ht (new java.util.Hashtable))
<Java-Object:java.util.Hashtable>
Jess> (call ?ht put "key1" "element1")
Jess> (call ?ht put "key2" "element2")
Jess> (call ?ht get "key1")
"element1"
```

- Manipulation of member variables:

```
Jess> (bind ?pt (new java.awt.Point))
<Java-Object:java.awt.Point>
Jess> (set-member ?pt x 37)
Jess> (set-member ?pt y 42)
Jess> (get-member ?pt x)
37
```

JESS Syntax – Rule Definition

(defrule <rule-name> [<doc-comment>]
[<fact-pattern>]* => [<function-call>]*)

- Example:

Jess> (deftemplate person
(slot firstName) (slot lastName) (slot age))

Jess> (defrule welcome-toddlers
"Give a special greeting to young children" (person {age < 3}) => (printout t "Hello, little one!"
crlf))

Jess> (assert (person (age 2)))

Jess> (run)

Hello, little one!

JESS Language – Rules use Standards

- Boolean expressions to evaluate slot content - within {}

  < <= > >= == != <> && | |

- Variable for reference after slot value - within ()

- Examples:

Jess> (defrule teenager ?p <- (person {age > 12 && age < 20} (firstName ?name))

=> (printout t ?name " is " ?p.age " years old." crlf))

Jess> (assert (person (age 15) (firstName Maria)))

Jess> (assert (person (age 18) (firstName Paul)))

Jess> (run)

Paul is 18 years old.

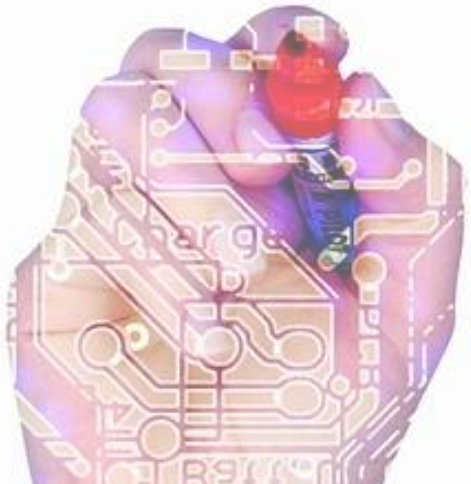
Maria is 15 years old.

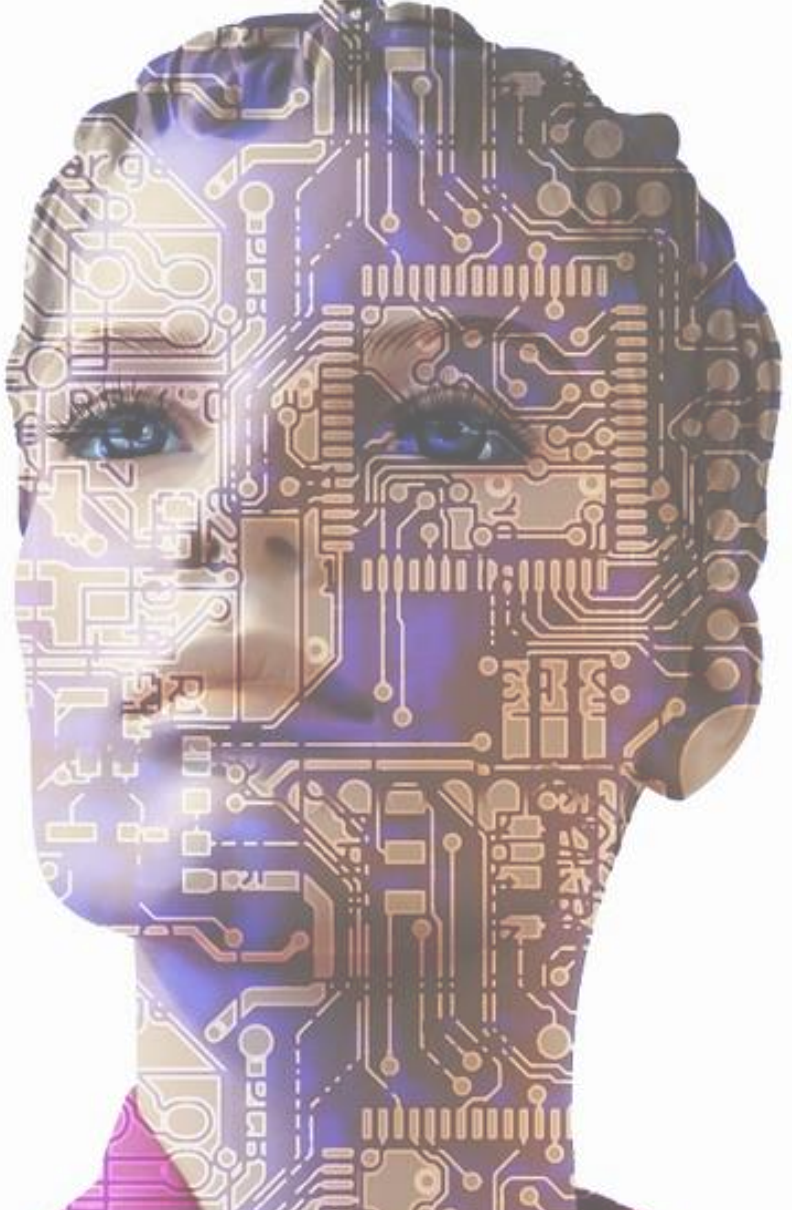
JESS Language – Rules use Standards

- Testing slots:
  - Literals
  - Variables (possibly not free)
  - & (and) | (or) ~ (not)
  - : (happens if the next function returns *TRUE*)
    - *(coord ?X&:(> ?X 10) ?)*
  - = equality between slot value and function return
    - *(coord ?X =(+ ?X 1))*
  - regular expressions surrounded by / .. /
    - *(person (firstName /A.*/))*

- *Other Examples:*
  - *(coord ?X ?X)*
  - *(coord ?X ?Y& ~?X)*
  - *(coord ?X& ~10 ?)*
  - *(coord ? 10|20)*
  - *(coord $?both) ; multislot*

JESS IN JAVA





JESS-JAVA API

Requirements:

1. Download JESS API: https://jess.sandia.gov/jess/download.shtml
   - Enter requested information to allow access
   - Download latest version: "Jess 7.1p2 classes, docs and samples (trial version)"
   - JESS APIs are located in: "Jess71p2.zip\Jess71p2\lib\"
   - JESS code examples are located in: "Jess71p2\examples*"
2. Create new JAVA Project and import JESS APIs into its build path
3. It is advisable to read the JESS documentation:
   - https://jess.sandia.gov/jess/docs/Jess71p2.pdf

JESS-JAVA API

JESS API:

- Classes
  - jess.Context
  - jess.Jesp
  - jess.JessException
  - **jess.Rete**
  - jess.Value
  - jess.ValueVector
  - ...
- Interfaces
  - jess.Userfunction
  - ...

JESS-JAVA API

Class *jess.Rete*:

- To access the Inference Engine, the *jess.Rete* object of this class must be called

Functions:

- *run()*, *reset()*, *clear()*, *assertFact()*, *retract()*, ...
- Execution of Jess command: *eval()*
- Add Jess's invoked functions into Java: *addUserfunction()*

jess.Userfunction Interface:

- Definition of Java functions invoked in Jess
- getName() and call() methods

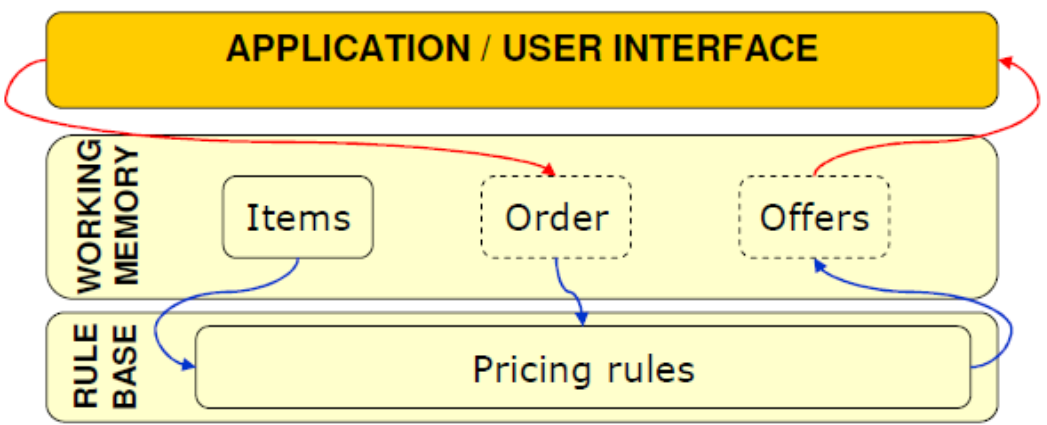
JESS-JAVA API (Code Example)

```
import jess.*;
public class ExSquare {
        public static void main(String[] str) {
                try {
                        Rete r = new Rete();
                        r.eval(" (deffunction square (?n) (return (* ?n ?n)) ) ");
                        Value v = r.eval("(square 3)");
                        System.out.println(v);
                } catch (JessException ex) {
                        System.err.println(ex);
}}}
```

JESS-JAVA API

Approach to determining discounts and offers in a store:

1. Create a Jess engine with the rules to apply and with the product data in catalogue
2. When an order arrives:
   - Add the order data to the working memory
   - Run the inference engine
   - Obtain from the Work Memory facts added by the rules



JESS-Java API (Example)

Rules define Examples:

(defrule 10%-volume-discount "Give 10% discount to everybody who spends more than € 100."

(Order {total > 100})

=>

(add (new Offer "10% volume discount"
(/ ?total 10))))

(defrule 25%-multi-item-discount "Give 25% discount on items customer buys 3 or more of.“

(OrderItem {quantity >= 3} (price ?price))

=>

(add (new Offer "25% multi-item discount"
(/ ?price 4))))

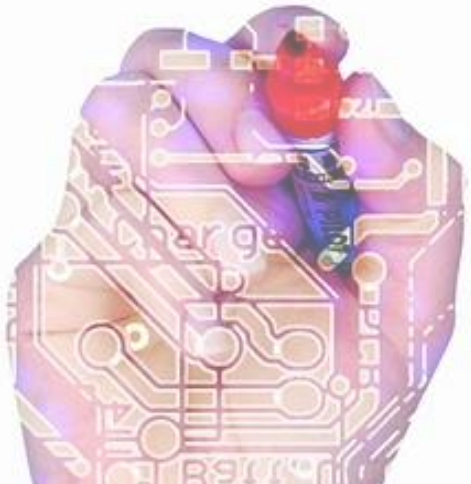
JESS-Java API (Example)

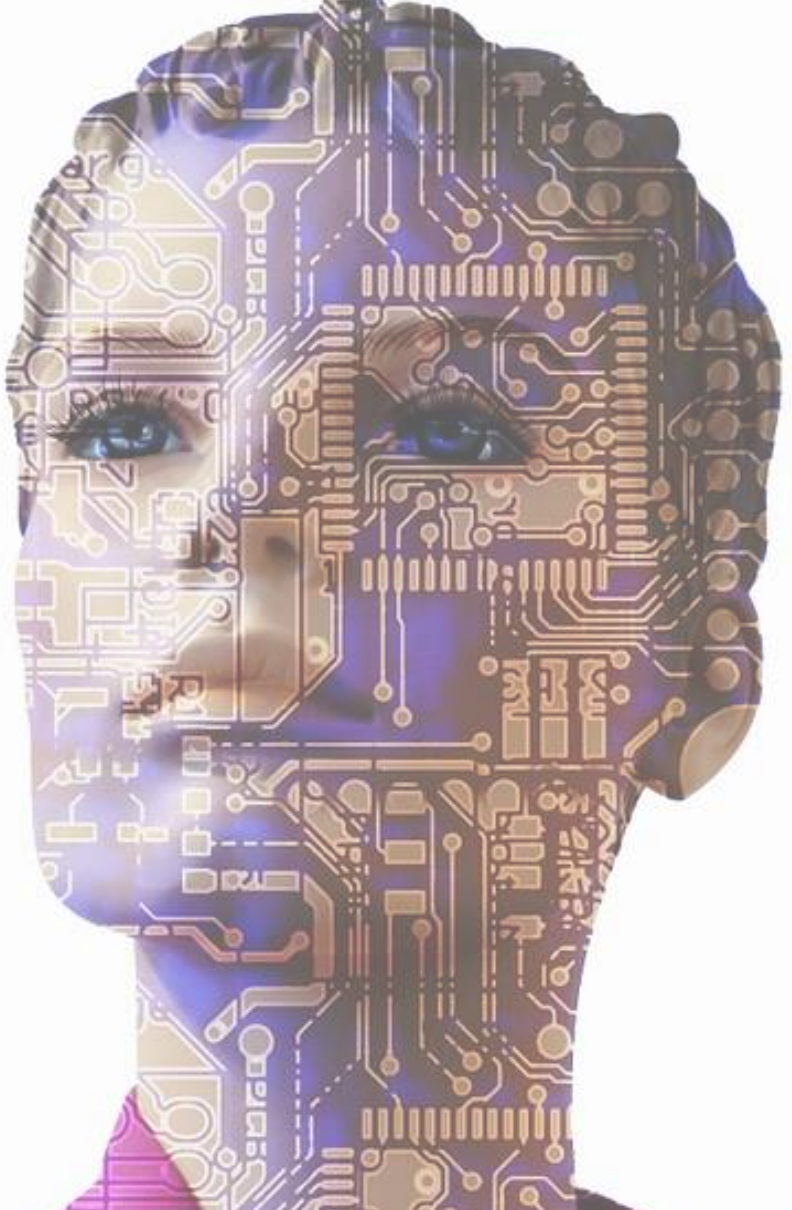
```
public class PricingEngine {
private Rete engine;
private WorkingMemoryMarker marker;

// Constructor
public PricingEngine(Database database) throws
JessException {
// Create a Jess rule engine
engine = new Rete();
engine.reset();

// Load the pricing rules
engine.batch("pricing.clp");

// Load the catalog data into working memory
engine.addAll(database.getCatalogItems());
// Mark end of catalog data for later
marker = engine.mark();
}
```

JESS-Java API (Example)

```
// Method for handling a new order
public Iterator run(Order orderNumber) throws
JessException {
// Remove any previous order data, leaving
// catalog data
engine.resetToMark(marker);
// Add the order and its contents to working
// memory
engine.add(order);
engine.add(order.getCustomer());
engine.addAll(order.getItems());
// Fire the rules that apply to this order
engine.run();

// Return the list of offers created by the rules
return engine.getObjects(new
Filter.ByClass(Offer.class));
}}
```

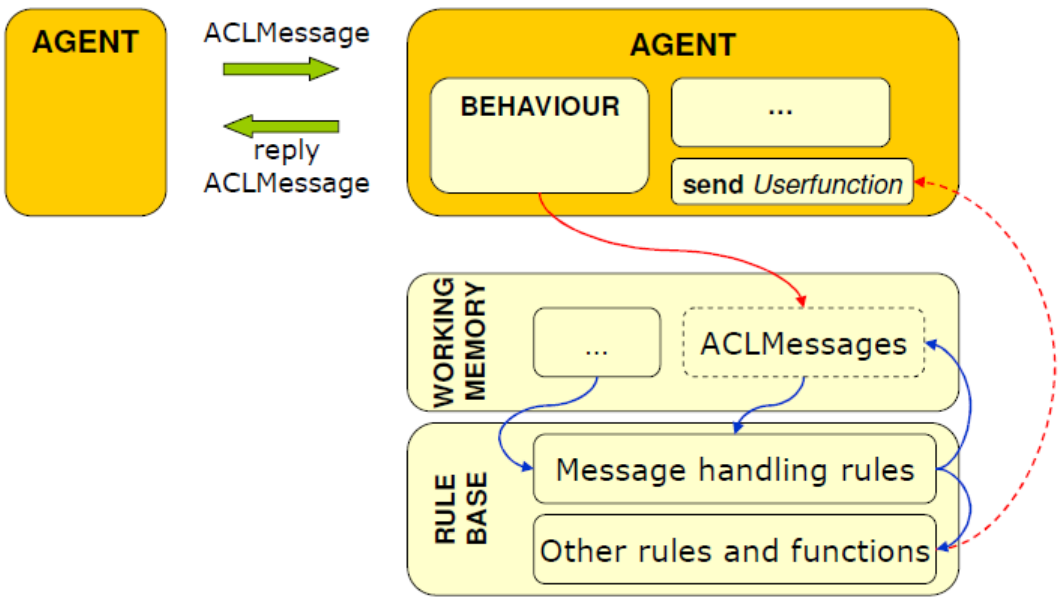
JESS IN JADE





JESS-JADE API (Example)

- Using Jess Rules to reply ACL Messages
  - Use Jess engine in an agent's *behavior*



JESS-JADE API (Example) - JessBehaviour

```
public class BasicJessBehaviour extends
CyclicBehaviour {
Rete jess;
// Constructor
BasicJessBehaviour(Agent agent) throws
JessException {
// create a Jess rule engine
jess = new Rete();
// create a fact with the agent's name: (i-am X)
jess.eval(" (deffacts Me " +
" (i-am " + myAgent.getName() + ") )");
// define Userfunction "send" to send
// ACLMessages
jess.addUserfunction(new JessSend(myAgent));
// load rules and functions into working memory
jess.batch("JadeAgent.clp");
jess.reset();
}
```

JESS-JADE API (Example) – ACLMessage receive

```
// Action method
public void action() {
// Receive a message
MessageTemplate mt = ... // some template
ACLMessage msg = myAgent.receive(mt);
if (msg != null) {
        try {
        // Convert ACLMessage into Jess fact and assert it
        jess.assertString(ACL2JessString(msg));
        // run Jess engine
        jess.run();
        } catch (JessException je) { ... }
} else block();
}
```

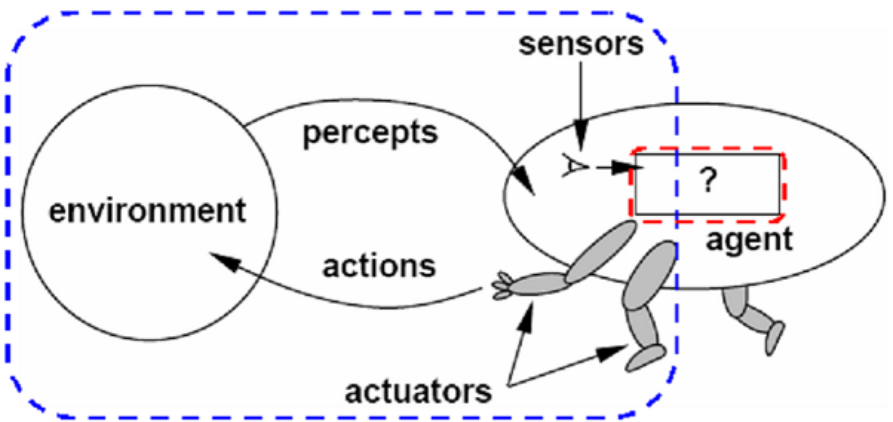
JESS-JADE API (Example) – *JessSend*

```
public class JessSend implements Userfunction {
Agent myAgent;

public JessSend(Agent a) { myAgent = a; }
public String getName() { return "send"; }

// JESS calls (send ?m) where ?m is an
// ACLMessage Jess fact
public Value call(ValueVector vv, Context ctx) throws
JessException {
// Get the Fact
Fact f = vv.get(1).factValue(ctx);
// Convert fact into ACLMessage
ACLMessage msg = JessFact2ACL(ctx, f);
                                        // Send the ACLMessage
                                        myAgent.send(msg);
                                        return Funcall.TRUE;
                                        }
                                    }
```

JESS-JADE API (Example) – JadeAgent.clp

```
; (limited) template of an ACLMessage
(deftemplate ACLMessage
(slot communicative-act)
(slot sender) (multislot receiver) (slot content))

; rule for handling CFP
(defrule proposal
?m <- (ACLMessage (communicative-act CFP)
(sender ?s) (content ?c) (receiver ?r))
(i-am ?r)
=>
(bind ?p (gen-proposal ?c))
(assert (ACLMessage (communicative-act PROPOSE)
(sender ?r) (receiver ?s)
(content ?p)))
(retract ?m) )

; rule for sending a message
(defrule send-a-message
?m <- (ACLMessage (sender ?s))
(i-am ?s)
=>
(send ?m)
(retract ?m) )
```

JESS used to implement the reasoning module of a JADE agent



JADE provides environment and facilitates the sending / receiving of messages

JESS enables the implementation of the agent's decision module in a declarative way

- JESS can be used in one of the many behaviors of an agent

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Filipe Gonçalves, Paulo Novais, César Analide