Review

Lecture 12: First-Order Logic

Chapter 8

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Review

Outline

- Why FOL?
- Syntax and semantics of FOL
- Using FOL
- Wumpus world in FOL
- Knowledge engineering in FOL
- Summary

Lecture 13: Knowledge engineering

Chap 8.4, 12, 16

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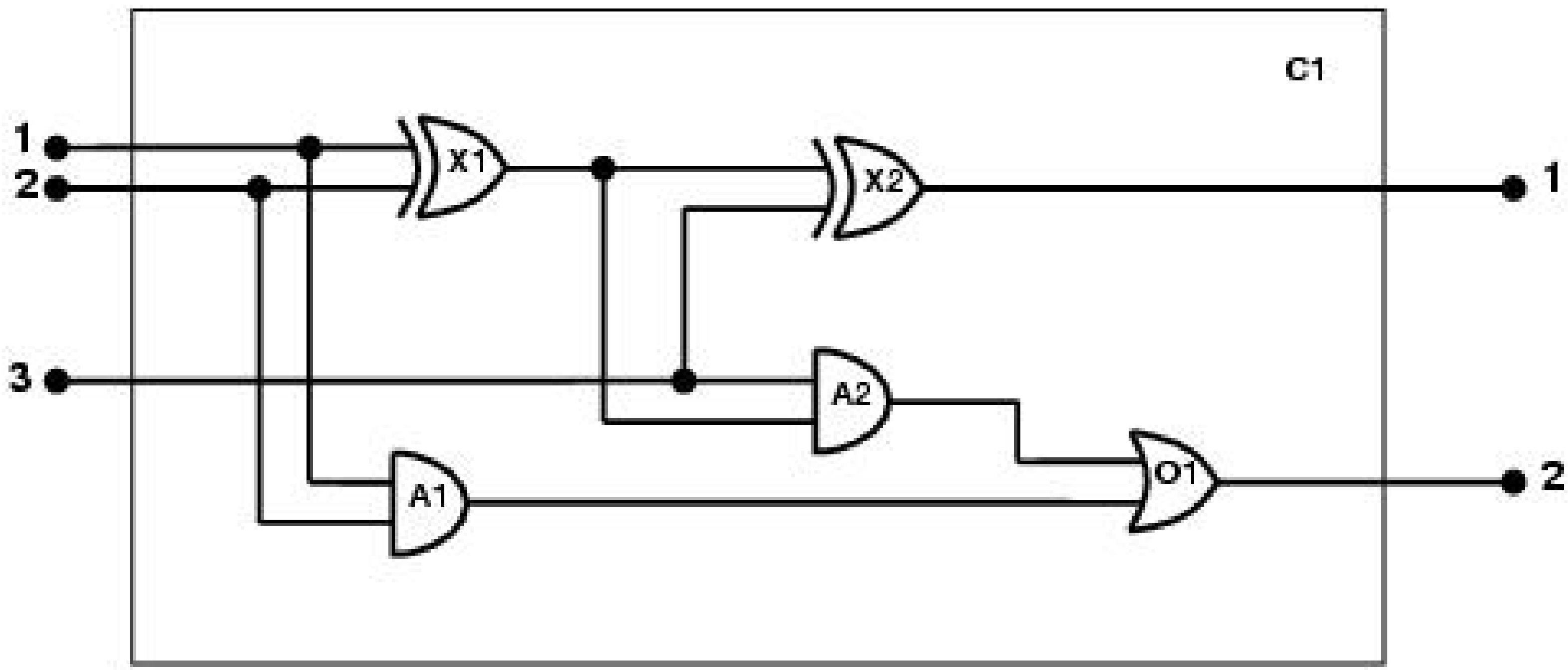
Knowledge engineering in FOL

1. Identify the task
2. Assemble the relevant knowledge
3. Decide on a vocabulary of predicates, functions, and constants
4. Encode general knowledge about the domain
5. Encode a description of the specific problem instance
6. Pose queries to the inference procedure and get answers
7. Debug the knowledge base

The electronic circuits domain

One-bit full adder



The electronic circuits domain

1. Identify the task
   - Does the circuit actually add properly? (circuit verification)
2. Assemble the relevant knowledge
   - Composed of wires and gates; Types of gates (AND, OR, XOR, NOT)
   - Irrelevant: size, shape, color, cost of gates
3. Decide on a vocabulary
   - Alternatives:

     $Type(X_1) = XOR$

     $Type(X_1, XOR)$

     $XOR(X_1)$

The electronic circuits domain

4. Encode general knowledge of the domain

axioms

- $\forall t_1,t_2 \text{ Connected}(t_1, t_2) \Rightarrow \text{Signal}(t_1) = \text{Signal}(t_2)$
- $\forall t \text{ Signal}(t) = 1 \vee \text{Signal}(t) = 0$
- $1 \neq 0$
- $\forall t_1,t_2 \text{ Connected}(t_1, t_2) \Rightarrow \text{Connected}(t_2, t_1)$
- $\forall g \text{ Type}(g) = OR \Rightarrow \text{Signal}(\text{Out}(1,g)) = 1 \Leftrightarrow \exists n \text{ Signal}(\text{In}(n,g)) = 1$
- $\forall g \text{ Type}(g) = AND \Rightarrow \text{Signal}(\text{Out}(1,g)) = 0 \Leftrightarrow \exists n \text{ Signal}(\text{In}(n,g)) = 0$
- $\forall g \text{ Type}(g) = XOR \Rightarrow \text{Signal}(\text{Out}(1,g)) = 1 \Leftrightarrow \text{Signal}(\text{In}(1,g)) \neq \text{Signal}(\text{In}(2,g))$
- $\forall g \text{ Type}(g) = NOT \Rightarrow \text{Signal}(\text{Out}(1,g)) \neq \text{Signal}(\text{In}(1,g))$

The electronic circuits domain

5. Encode the specific problem instance

$Type(X_1) = XOR$
$Type(X_2) = XOR$
$Type(A_1) = AND$
$Type(A_2) = AND$
$Type(O_1) = OR$

$Connected(Out(1,X_1),In(1,X_2))$
$Connected(Out(1,X_1),In(2,A_2))$
$Connected(Out(1,A_2),In(1,O_1))$
$Connected(Out(1,A_1),In(2,O_1))$
$Connected(Out(1,X_2),Out(1,C_1))$
$Connected(Out(1,O_1),Out(2,C_1))$

$Connected(In(1,C_1),In(1,X_1))$
$Connected(In(1,C_1),In(1,A_1))$
$Connected(In(2,C_1),In(2,X_1))$
$Connected(In(2,C_1),In(2,A_1))$
$Connected(In(3,C_1),In(2,X_2))$
$Connected(In(3,C_1),In(1,A_2))$

The electronic circuits domain

6. Pose queries to the inference procedure

   What are the possible sets of values of all the terminals for the adder circuit?

   $\exists i_1,i_2,i_3,o_1,o_2$ Signal(In(1,C_1)) = $i_1 \wedge$ Signal(In(2,C_1)) = $i_2 \wedge$ Signal(In(3,C_1)) = $i_3 \wedge$ Signal(Out(1,C_1)) = $o_1 \wedge$ Signal(Out(2,C_1)) = o_2

7. Debug the knowledge base

   May have omitted assertions like $1 \neq 0$, so the system will be unable to prove any outputs for circuit. Try to find the bugs!

Knowledge engineering

- Conception
  - *The process of building intelligent knowledge-based system*
- The six basic phases
  - 1 Problem assessment
  - 2 Data and knowledge acquisition
  - 3 Development of a prototype system
  - 4 Development of a complete system
  - 5 Evaluation and revision of the system
  - 6 Integration and maintenance of the system

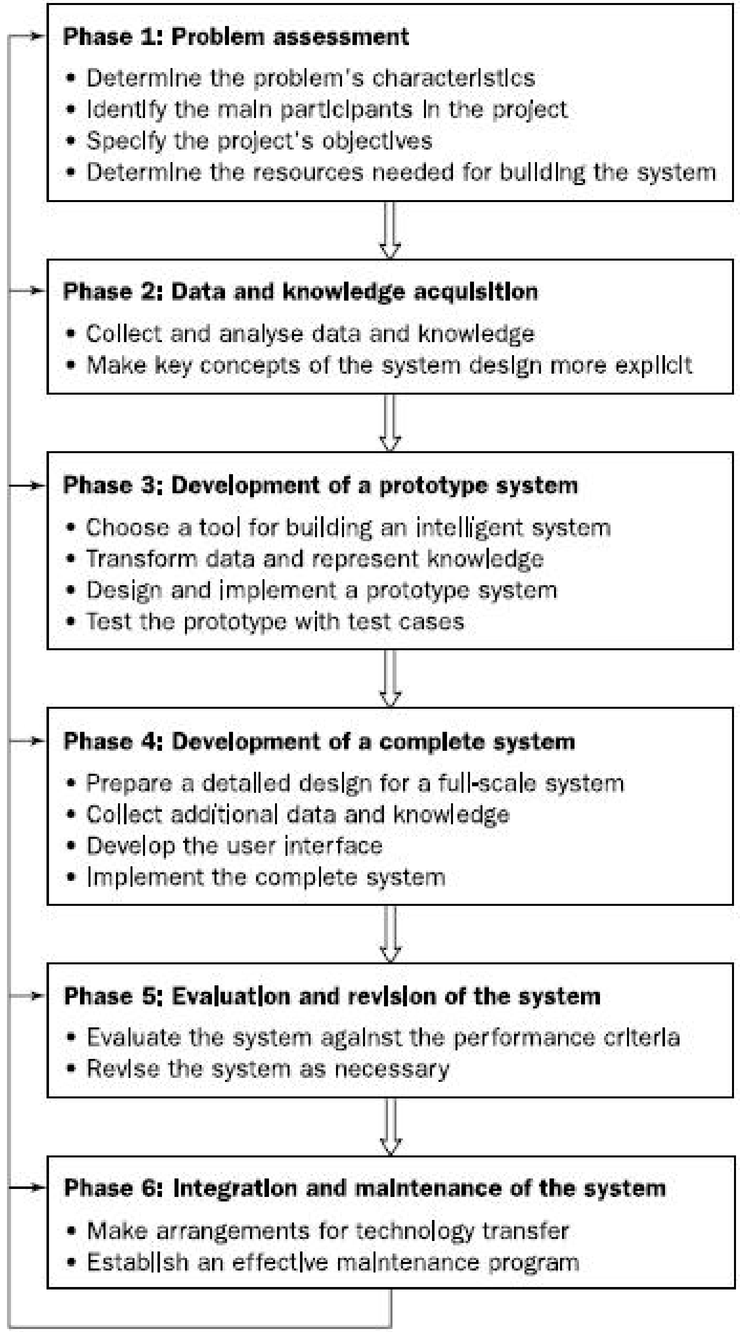


Figure 1 The process of knowledge engineering

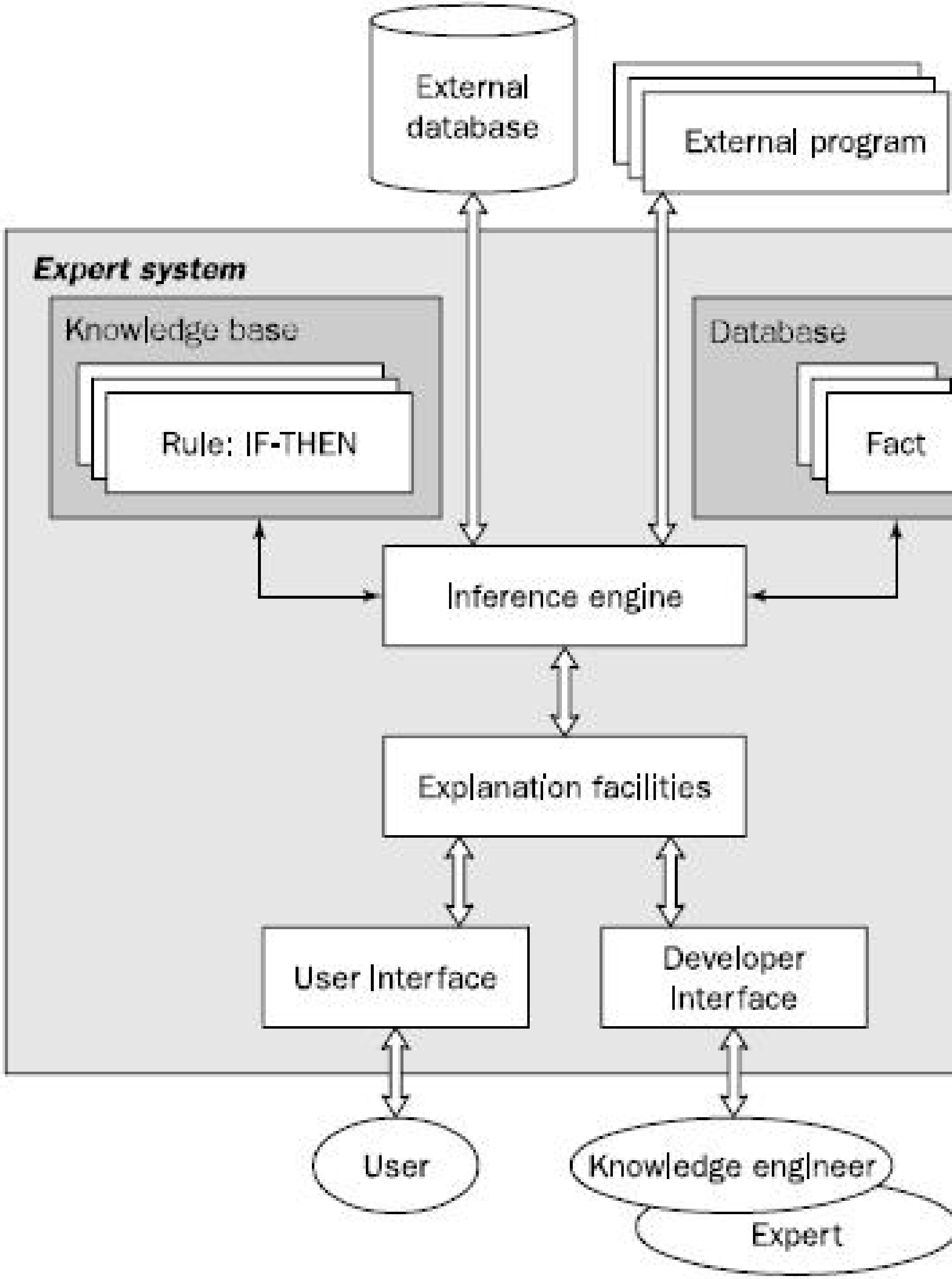


Figure 2.3 Complete structure of a rule-based expert system

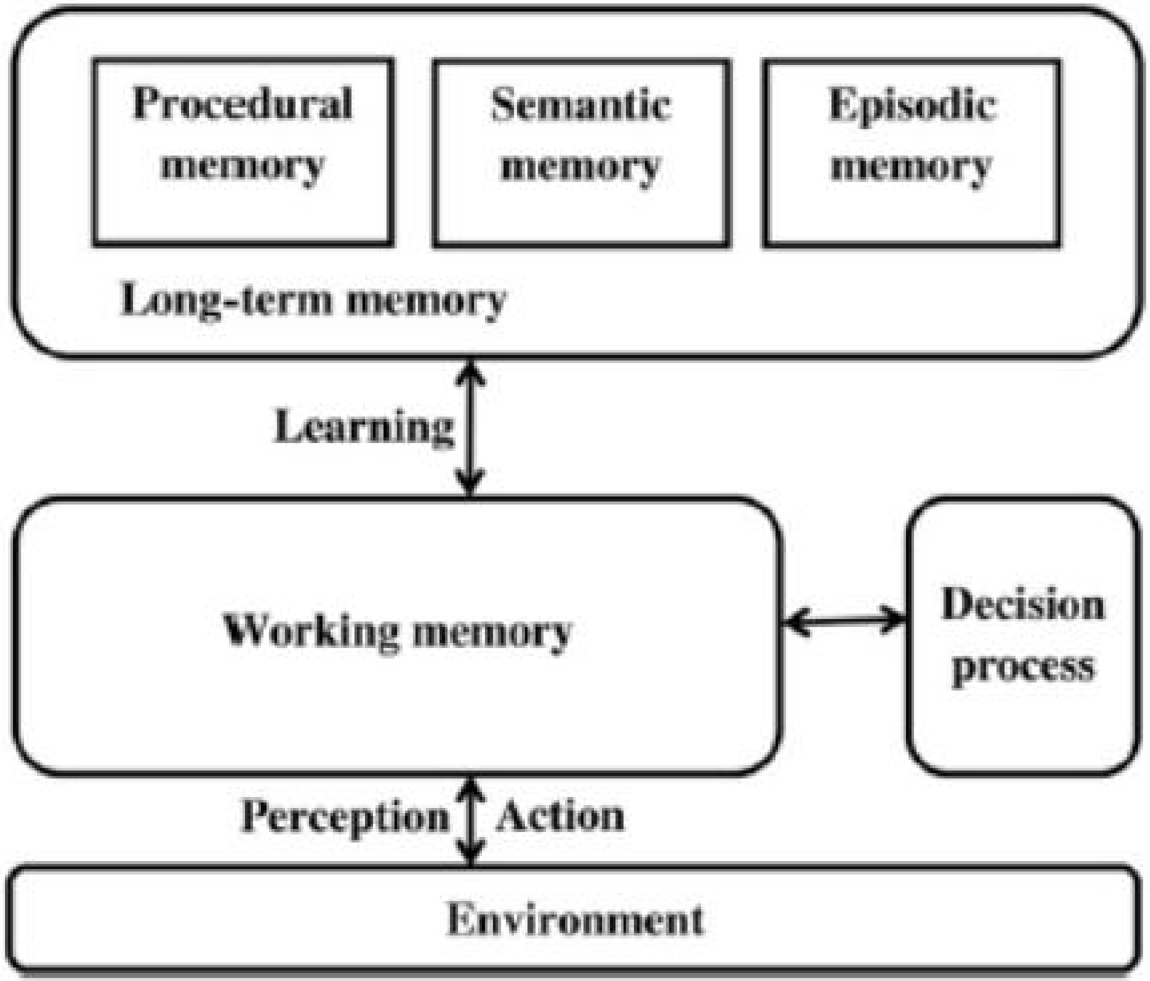


Fig.3 The general architecture of SOAR

.The main components of 'traditional' Soar are the Long-Term Memory and the Working Memory. Additional details are from Soar 9.

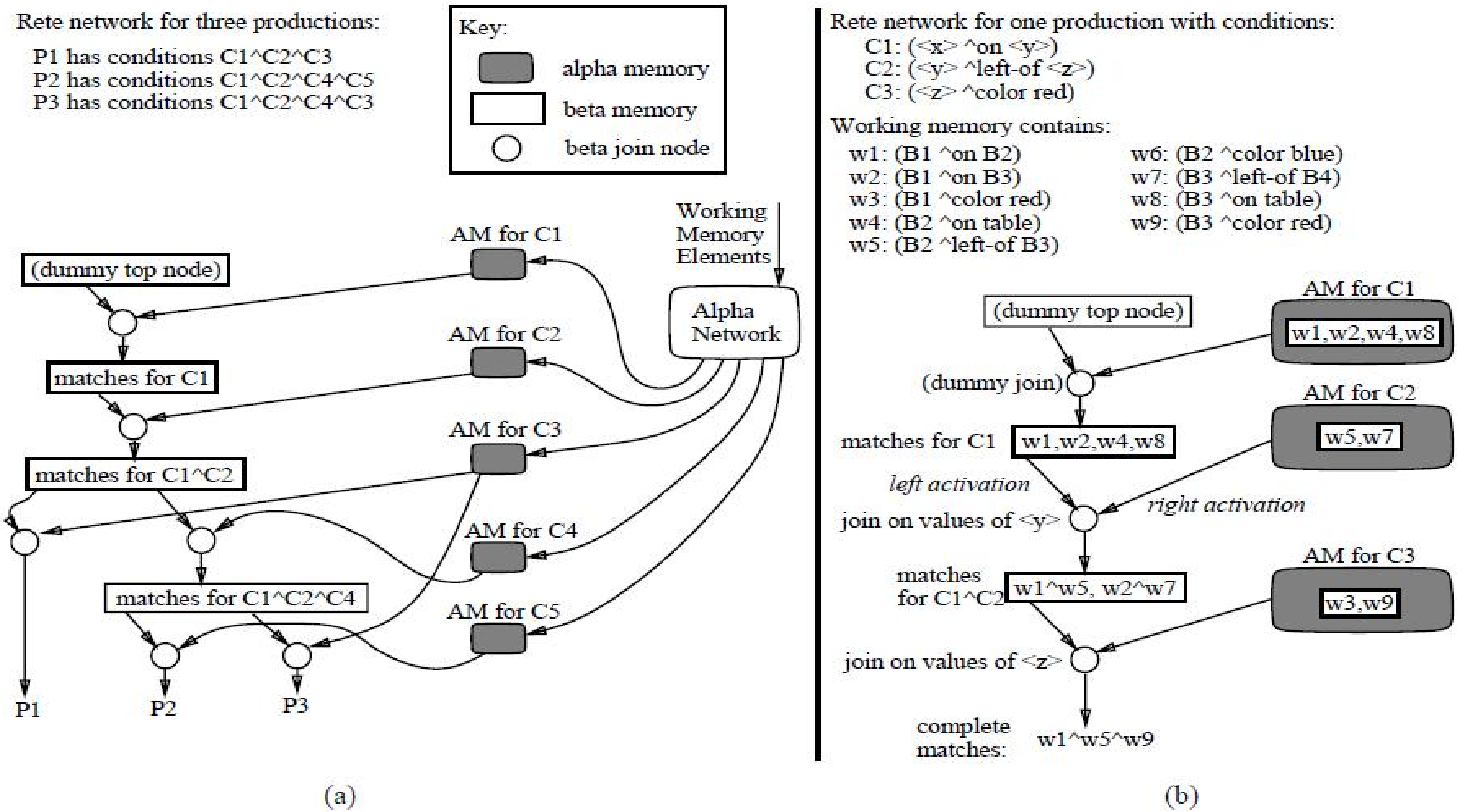


Figure 4 Rete net in Soar

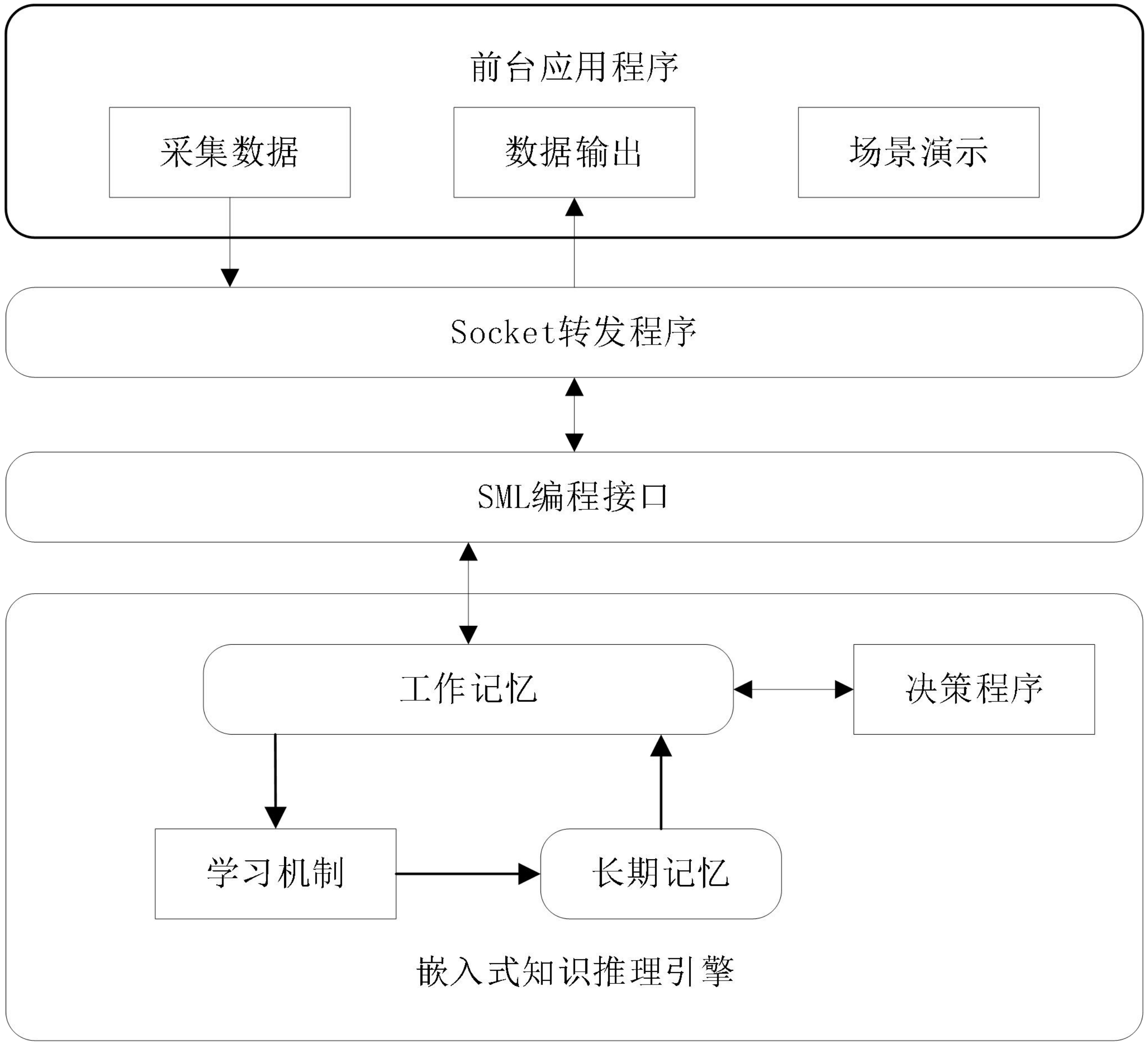


Fig.4 Embedded SOAR based KE

Challenges for KE

- Knowledge acquisition
  - Automatic ~
  - Autonomous ~
  - Limitation of KB
  - Limited Space
  - ……
  - Limitation of Inference
  - Limited Time
  - ……

Ideas and discussions

- KE for Embodied Agents
- KE for AlphaGo
- Knowledges and Skills

Summary

- Conclusions about Knowledge-based Agent
  - P313: Summary
  - More points

- Reading
  - Chapter 8.4, 12, ES: K/I/D, 16.7
- Exercises:

  Exercise 8.27

Assignment

- Reading
  - Chapter 8.4, 12, ES: K/I/D, 16.7
- Exercises:

  Exercise 8.10, 8.1

  Exercise 8.27