INSTITUT TEKNOLOGI BANDUNG
1920

Modul 6: Rule-based System

01 What & Why

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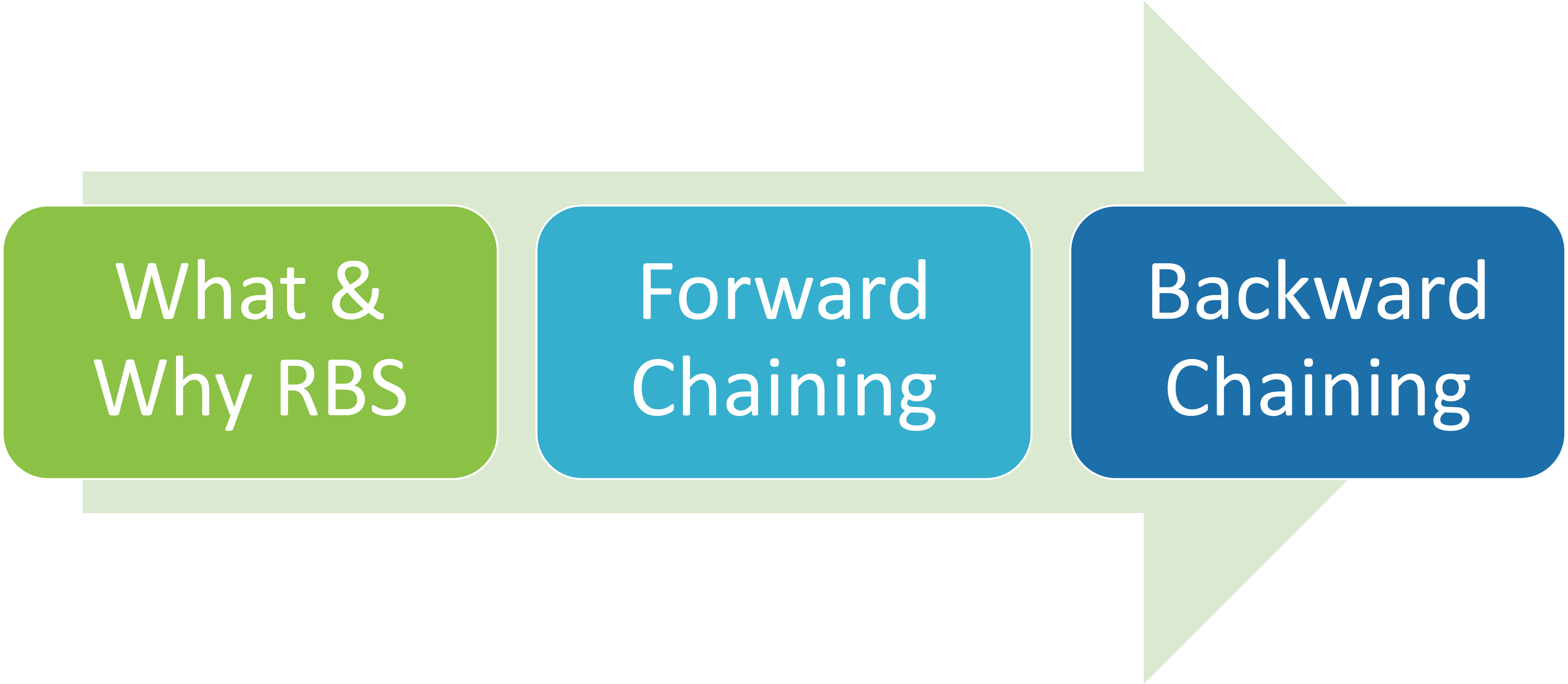
KK IF – Teknik Informatika – STEI ITB

Inteligensi Buatan
(*Artificial Intelligence*)

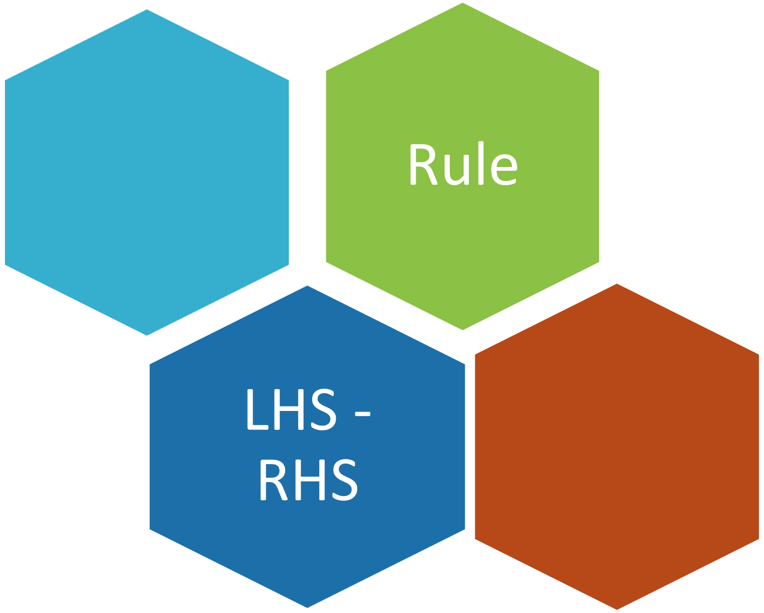
Rule-based System



Rule-based System (RBS): What

KBS with rule as knowledge representation

Rule =
precondition - action



Rule

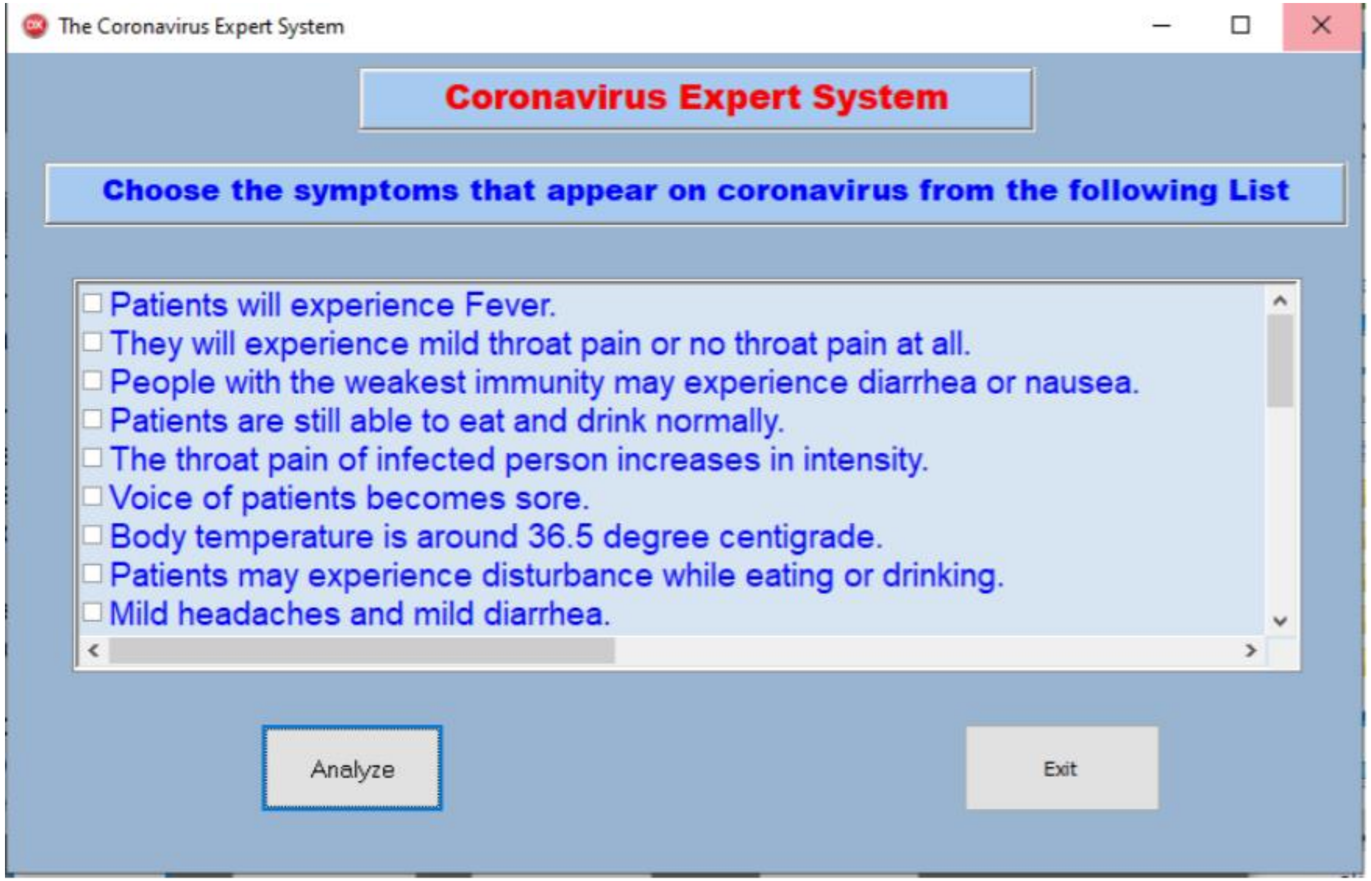
LHS - RHS

Rule-based System: Why

Rule-based system: the simplest and most widespread solution in the real world

Rule: the simplest and most common knowledge representation

Rule-based ES shell: CLIPS



The Coronavirus Expert System
Coronavirus Expert System
Choose the symptoms that appear on coronavirus from the following List
Analyze
Exit

□ Patients will experience Fever.
□ They will experience mild throat pain or no throat pain at all.
□ People with the weakest immunity may experience diarrhea or nausea.
□ Patients are still able to eat and drink normally.
□ The throat pain of infected person increases in intensity.
□ Voice of patients becomes sore.
□ Body temperature is around 36.5 degree centigrade.
□ Patients may experience disturbance while eating or drinking.
□ Mild headaches and mild diarrhea.

Salman, F. M., & Abu-Naser, S. S. (2020). Expert System for COVID-19 Diagnosis. International Journal of Academic Information Systems Research (IJAISR)

RBS: Why

Hybrid Approach:
RBS+ML

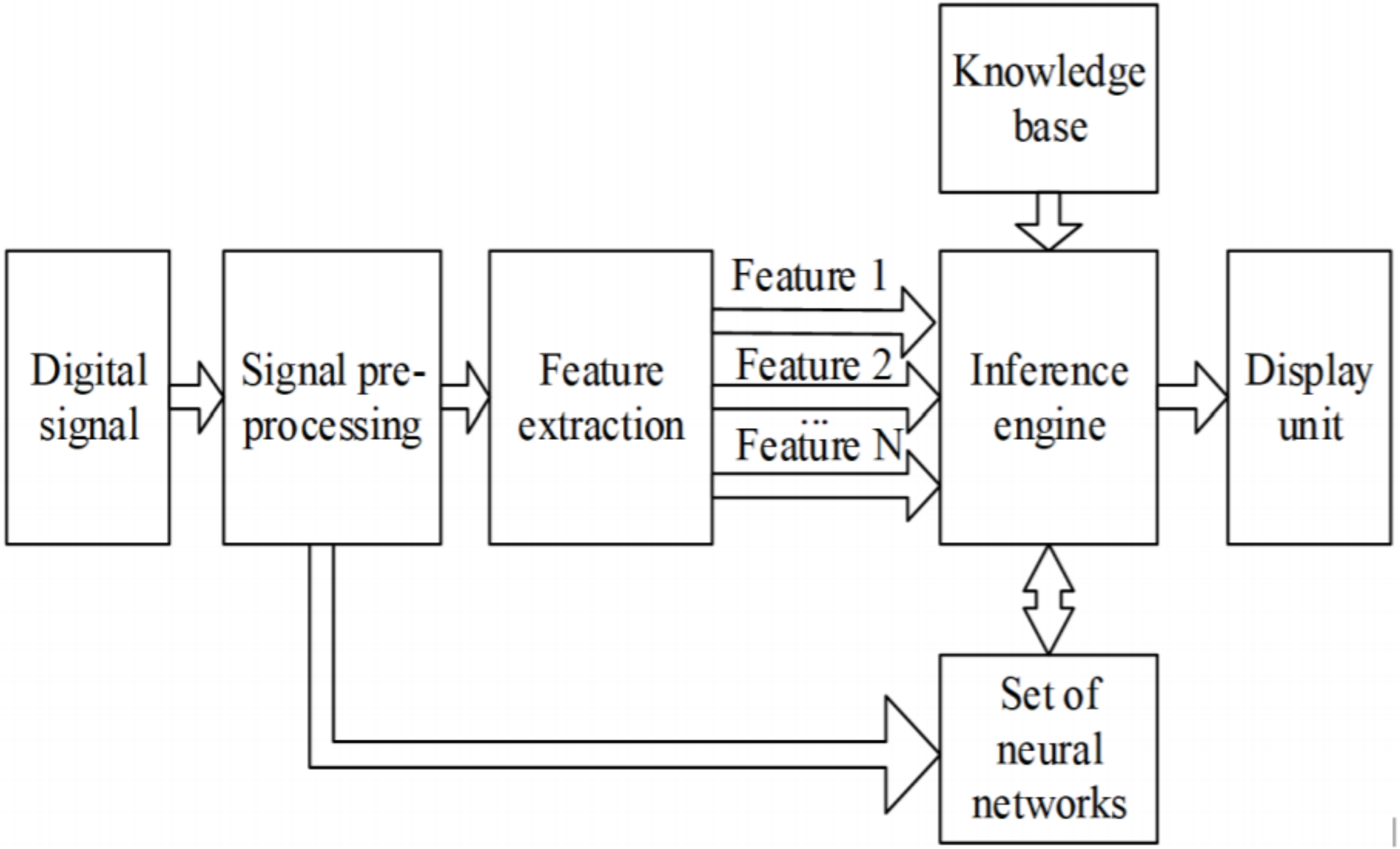
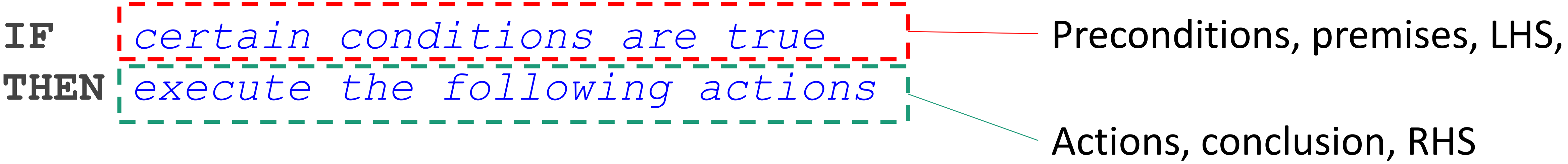


Figure 1. Structure diagram of the software for signal classification.

Donskih, D. N., & Barabanov, V. F. (2020, March). Usage of production-based expert system and neural network for signal recognition. In *Journal of Physics: Conference Series* (Vol. 1479, No. 1, p. 012060). IOP Publishing.

Rule: Logical Implication



IF *certain conditions are true*

THEN *execute the following actions*

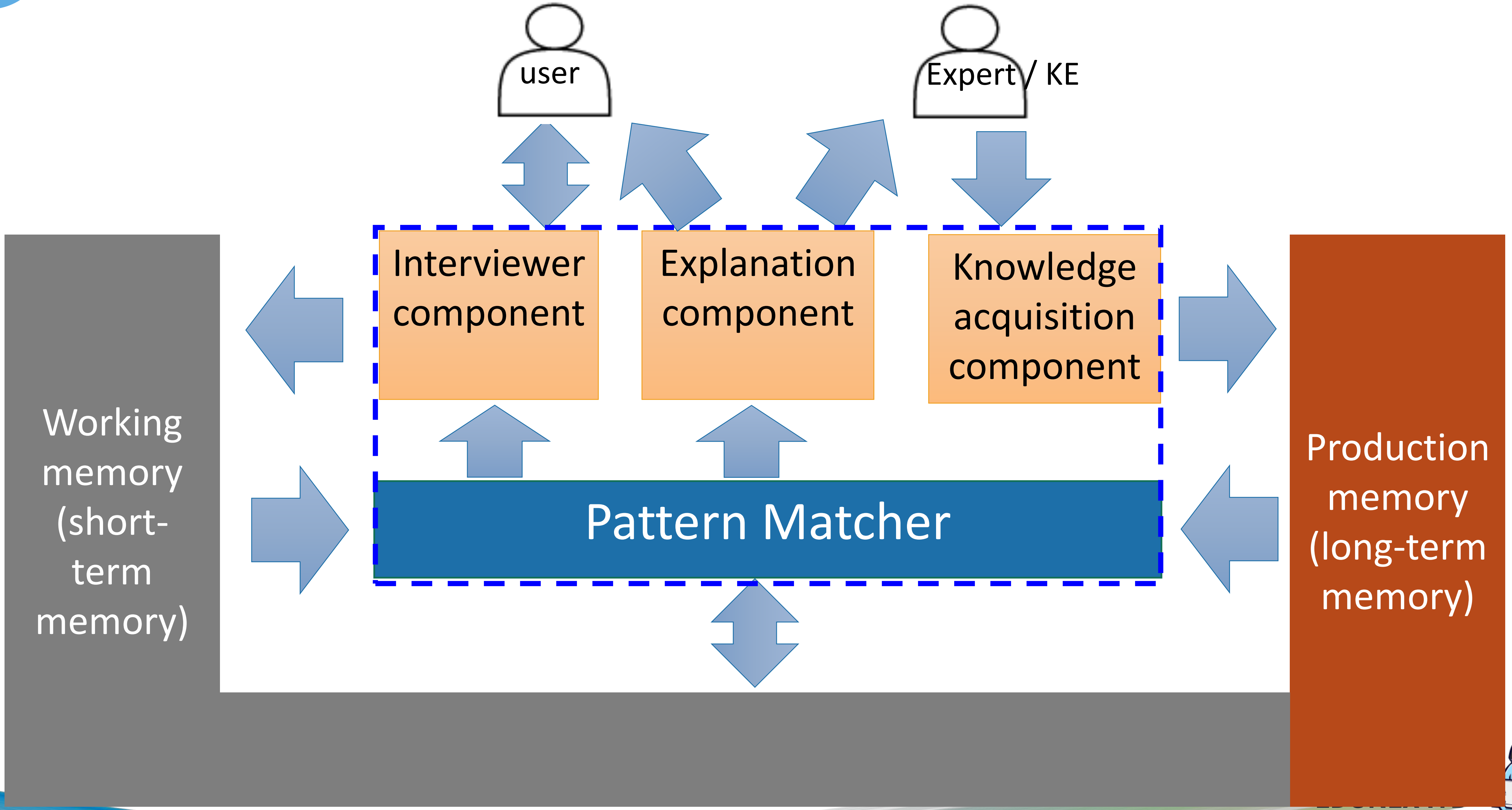
Preconditions, premises, LHS,

Actions, conclusion, RHS

CLIPS: C Language Integrated Production System

```
(defrule R
   (is-a ?x horse)
   (is-parent-of ?x ?y)
   (is-fast ?y)
=>
   (assert (is-valuable ?x))
)
```

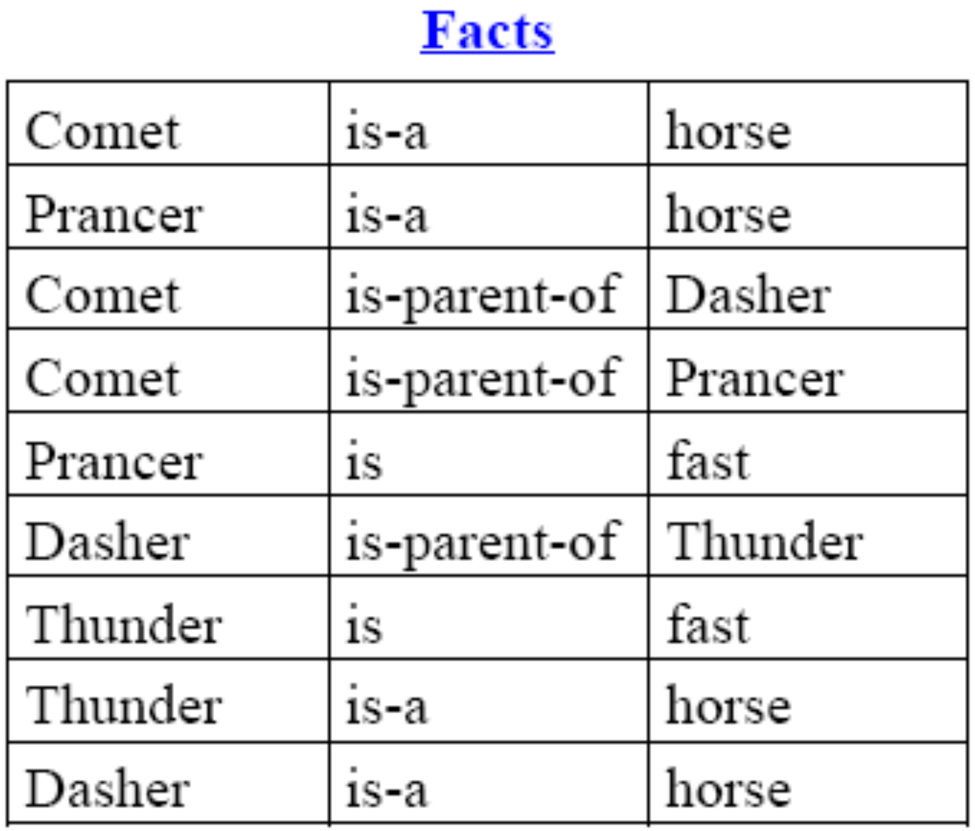
General Architecture of RBS


user
Expert / KE
Interviewer component
Explanation component
Knowledge acquisition component
Working memory (short-term memory)
Pattern Matcher
Production memory (long-term memory)

Puppe, F. (1993). *Systematic Introduction to Expert Systems* . Springer, Berlin, Heidelberg.

Pattern Matching: Example

IF: is-a (x, horse),
is-parent-of(x, *y),*
is-fast(y)
THEN: *x* is valuable



Facts

Comet	is-a	horse
Prancer	is-a	horse
Comet	is-parent-of	Dasher
Comet	is-parent-of	Prancer
Prancer	is	fast
Dasher	is-parent-of	Thunder
Thunder	is	fast
Thunder	is-a	horse
Dasher	is-a	horse

Example: Rule in CLIPS

```
 (defrule R
    (is-a ?x horse)
    (is-parent-of ?x ?y)
    (is-fast ?y)
=>
    (assert (is-valuable ?x))
)
 (defrule output
    (is-valuable ?x)
=>
    (printout t ?x " is valuable" crlf)
)
```

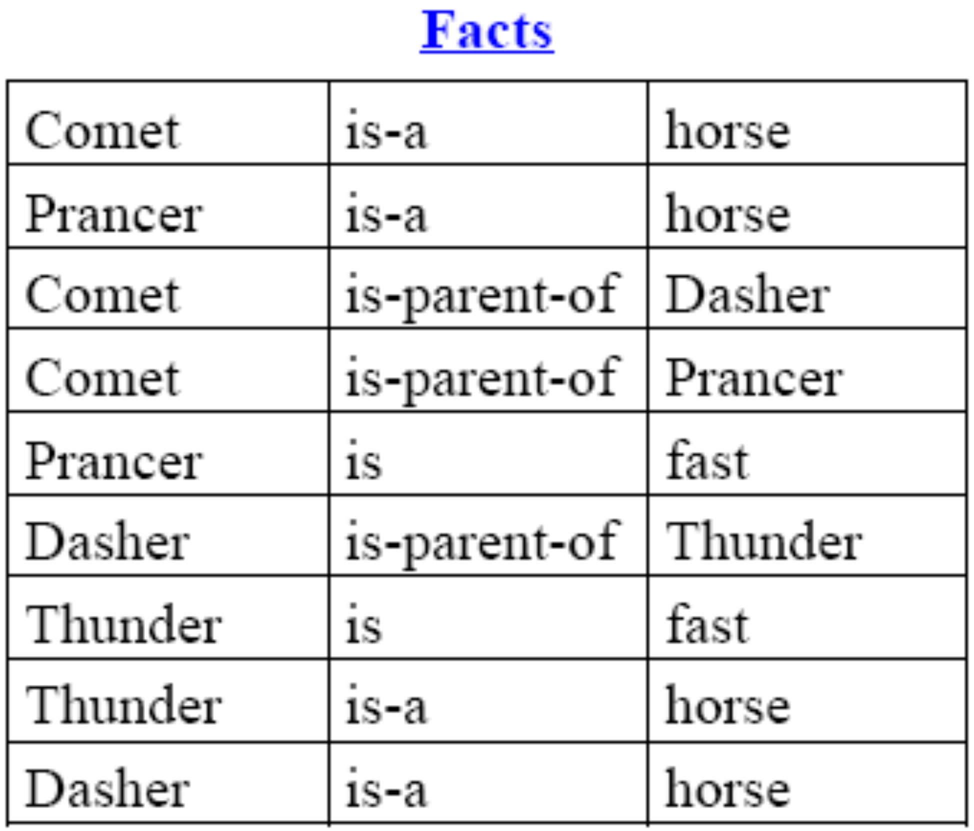
IF: is-a (x, horse),
is-parent-of(x, *y),*
is-fast(y)
THEN: *x* is valuable

Example: Facts in CLIPS

```
(deffacts horse
   (is-a Comet horse)
   (is-a Prancer horse)
   (is-a Thunder horse)
   (is-a Dasher horse)
)

(deffacts parent
   (is-parent-of Comet Dasher)
   (is-parent-of Comet Prancer)
   (is-parent-of Dasher Thunder)
)

(deffacts fast
   (is-fast Prancer)
   (is-fast Thunder)
)
```



Facts

Comet	is-a	horse
Prancer	is-a	horse
Comet	is-parent-of	Dasher
Comet	is-parent-of	Prancer
Prancer	is	fast
Dasher	is-parent-of	Thunder
Thunder	is	fast
Thunder	is-a	horse
Dasher	is-a	horse

Example in CLIPS: Run

```
CLIPS> (load "horse.clp")
Defining deffacts: horse
Defining deffacts: parent
Defining deffacts: fast
Defining defrule: R +j+j+j+j
Defining defrule: output +j+j
TRUE
CLIPS> (reset)

CLIPS> (run)
Dasher is valuable
Comet is valuable
CLIPS>
```

```
CLIPS> (facts)
f-0     (initial-fact)
f-1     (is-a Comet horse)
f-2     (is-a Prancer horse)
f-3     (is-a Thunder horse)
f-4     (is-a Dasher horse)
f-5     (is-parent-of Comet Dasher)
f-6     (is-parent-of Comet Prancer)
f-7     (is-parent-of Dasher Thunder)
f-8     (is-fast Prancer)
f-9     (is-fast Thunder)
f-10    (is-valuable Dasher)
f-11    (is-valuable Comet)
For a total of 12 facts.
```

CLIPS: Watch

```
FIRE    1 R: f-4,f-7,f-9
f-4     (is-a Dasher horse)
f-7     (is-parent-of Dasher Thunder)
f-9     (is-fast Thunder)
==> f-10    (is-valuable Dasher)
```

```
(defrule R
    (is-a ?x horse)
    (is-parent-of ?x ?y)
    (is-fast ?y)
=>
    (assert (is-valuable ?x))
)
```

```
FIRE    3 R: f-1,f-6,f-8
==> f-11    (is-valuable Comet)
```

```
CLIPS> (reset)
<== f-0     (initial-fact)
==> f-0     (initial-fact)
==> f-1     (is-a Comet horse)
==> f-2     (is-a Prancer horse)
==> f-3     (is-a Thunder horse)
==> f-4     (is-a Dasher horse)
==> f-5     (is-parent-of Comet Dasher)
==> f-6     (is-parent-of Comet Prancer)
==> f-7     (is-parent-of Dasher Thunder)
==> f-8     (is-fast Prancer)
==> f-9     (is-fast Thunder)
CLIPS> (run)
FIRE    1 R: f-4,f-7,f-9
==> f-10    (is-valuable Dasher)
FIRE    2 output: f-10
Dasher is valuable
FIRE    3 R: f-1,f-6,f-8
==> f-11    (is-valuable Comet)
FIRE    4 output: f-11
Comet is valuable
CLIPS>
```

Rule Inference Methods

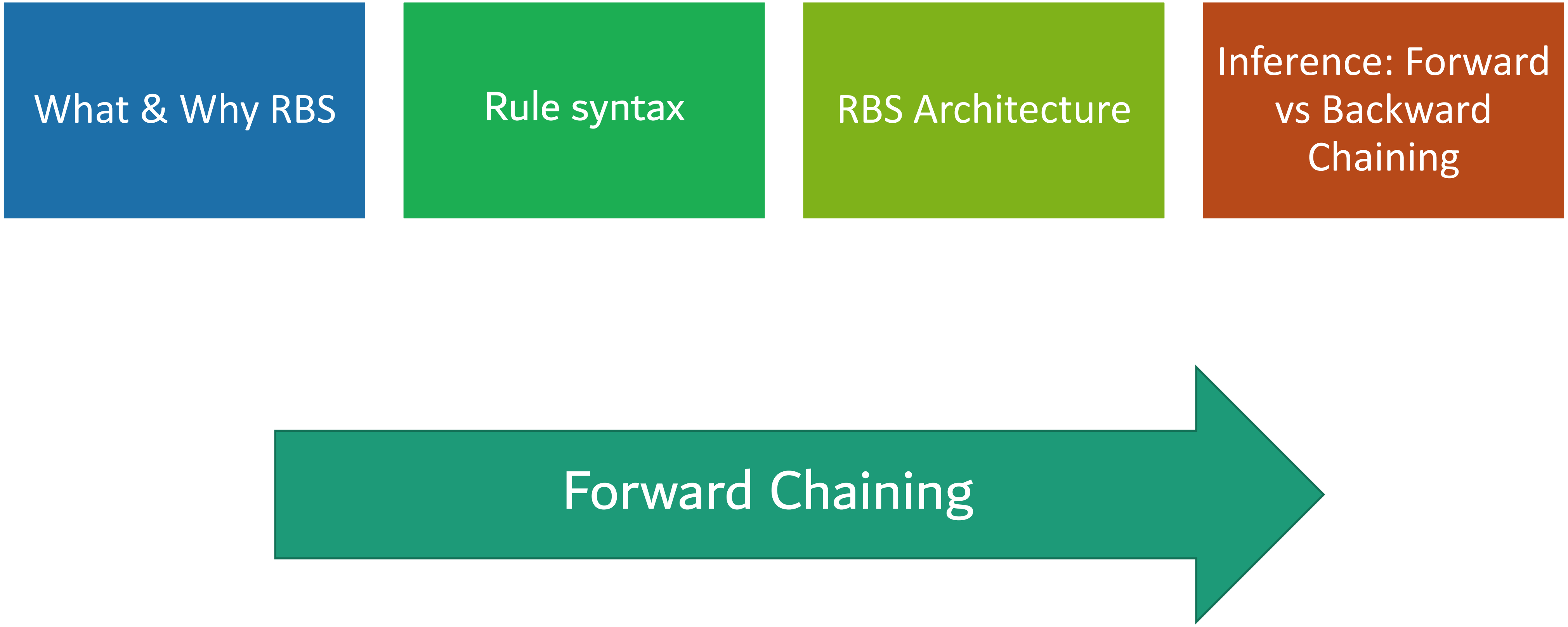
Forward chaining

- Data driven
- Match LHS

Backward chaining

- Goal driven
- Match RHS

Summary



What & Why RBS

Rule syntax

RBS Architecture

Inference: Forward vs Backward Chaining

Forward Chaining

Modul 6: Rule-based System

02 Forward Chaining

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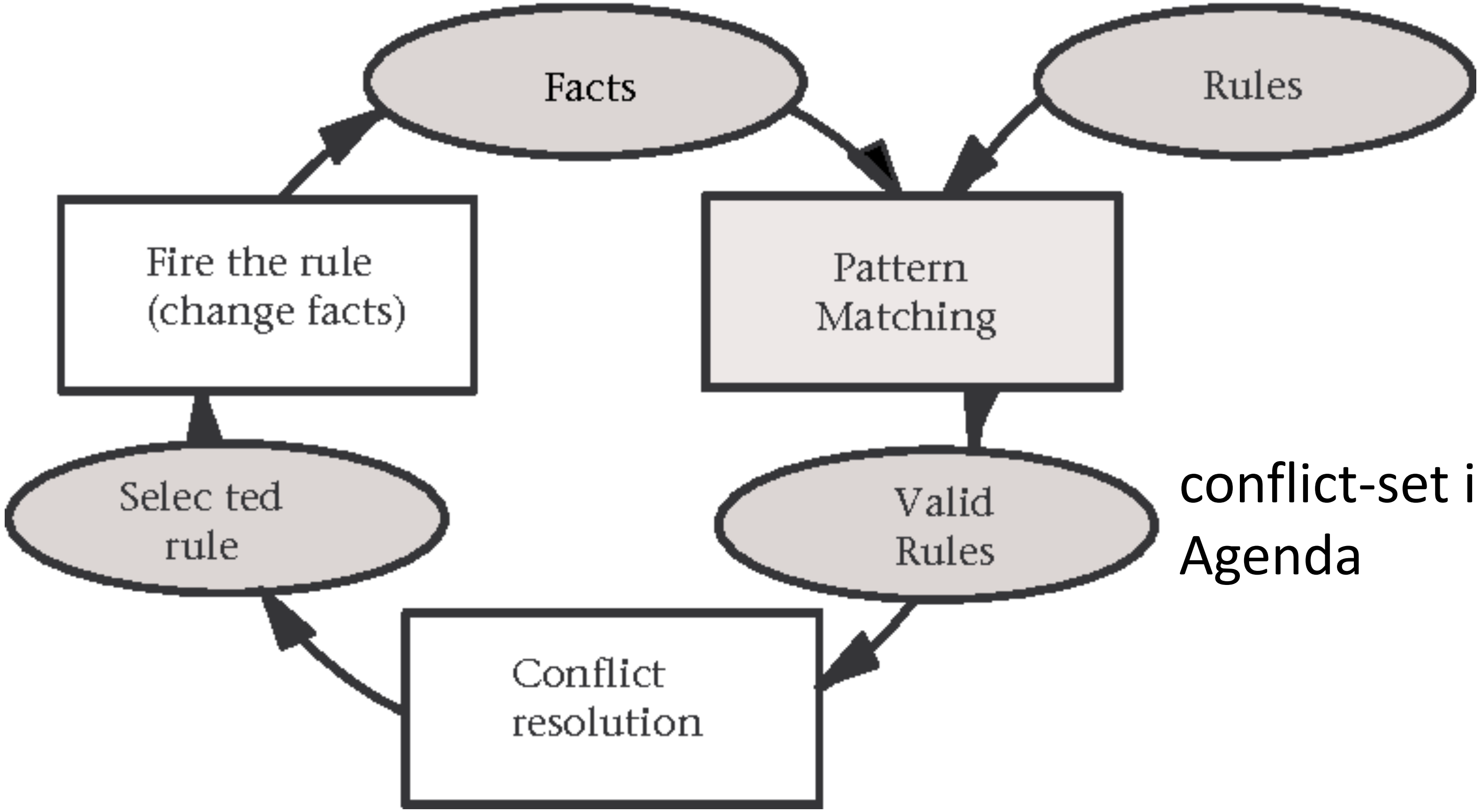
Inteligensi Buatan
(*Artificial Intelligence*)

Forward Chaining: Recognize-Act Cycle



conflict-set in Agenda

Barachini, F. (1994). Frontiers in run-time prediction for the production-system paradigm. *AI Magazine*, *15*(3), 47-47.

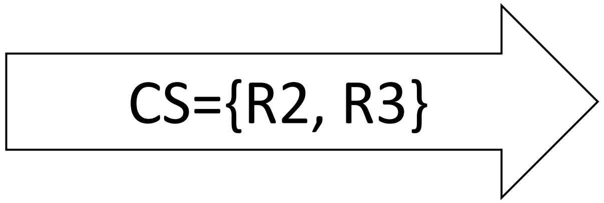
Forward Chaining: Pseudo code

```
data ← initial facts
repeat
    conflictSet ← determine set of rules whose
                  preconditions are satisfied by data
                  //preselection
    R ← select a rule from conflictSet by conflict-
        resolving strategy
    data ← result of applying action part of R to data
until data satisfied termination condition
```

RBS Example

Rule-base:
R1: IF (lecturing X) AND (marking-practicals X) THEN ADD (overworked X)
R2: IF (month february) THEN ADD (lecturing alison)
R3: IF (month february) THEN ADD (marking-practicals alison)
R4: IF (overworked X) OR (slept-badly X) THEN ADD (bad-mood X)
R5: IF (bad-mood X) THEN DELETE (happy X)
R6: IF (lecturing X) THEN DELETE (researching X)

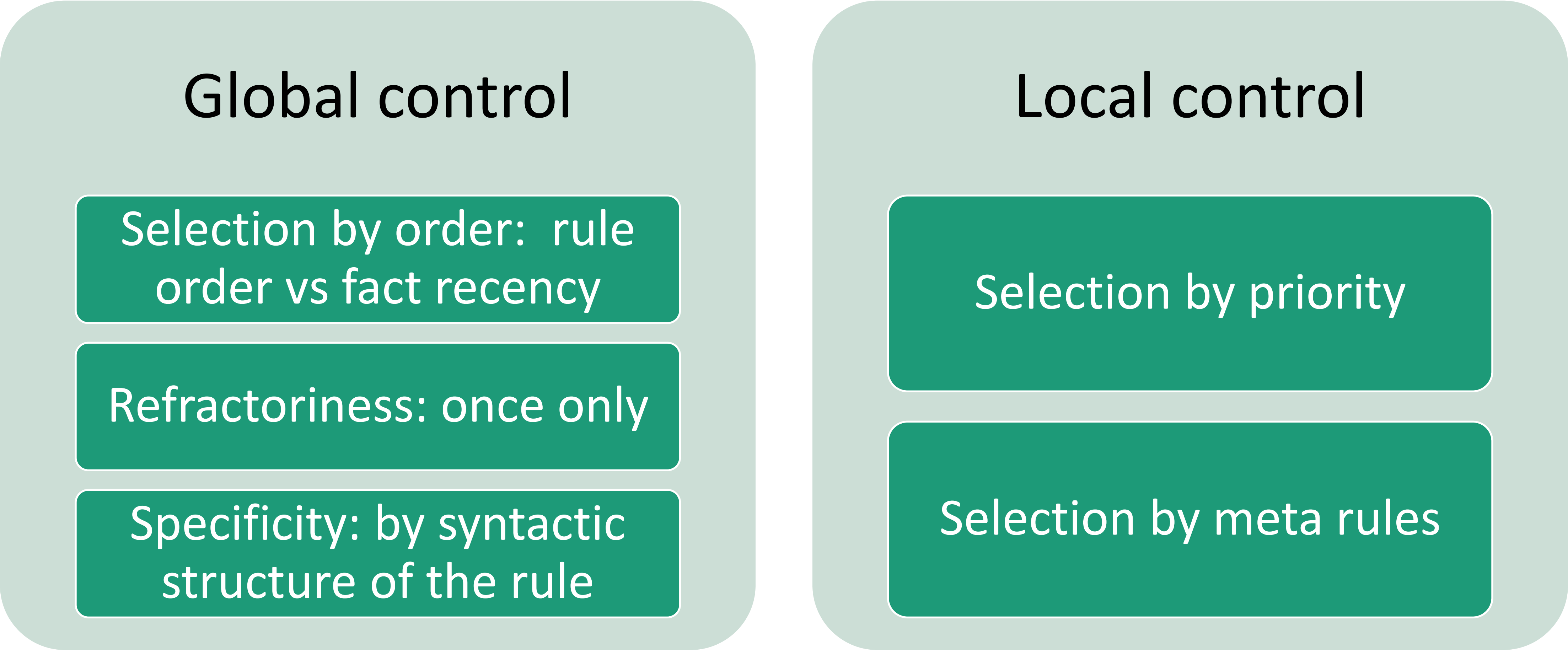
Facts:
(month february)
(happy alison)
(researching alison)



CS={R2, R3}

R=?

Conflict-resolution Strategy



Global control

- Selection by order: rule order vs fact recency
- Refractoriness: once only
- Specificity: by syntactic structure of the rule

Local control

- Selection by priority
- Selection by meta rules

Refractoriness

→ gk boleh pakai rules itu lg utk data fakta yg sama (ga boleh ngulang pakai rulesnya)

Do not select a rule that has just been applied with the same values of its variables (Brachman, 2004).

Rule-base:

R1: IF (lecturing X) AND (marking-practicals X) THEN ADD (overworked X)

R2: IF (month february) THEN ADD (lecturing alison)

R3: IF (month february) THEN ADD (marking-practicals alison)

R4: IF (overworked X) OR (slept-badly X) THEN ADD (bad-mood X)

R5: IF (bad-mood X) THEN DELETE (happy X)

R6: IF (lecturing X) THEN DELETE (researching X)

Facts:
(month february)
(happy alison)
(researching alison)

Iteration	CS	R
1	{R2, R3}	R2
2	{R2, R3, R6}	R3
3	etc….	

Selection by Order (with Refractoriness)

Knowledge-base:

```
R1: if (priority second)
then out("print second")
R2: if (priority first)
then out("print first")
R3: if (priority third)
then out("print third")
```

Facts:

```
(priority first)
(priority second)
(priority third)
```

- Selection by rule order (FIFO):

print second
print first
print third

iterasi selesai
saat tidak ada
rules yg bisa
dipilih lagi

- Selection by fact (recency) order (LIFO):

print third
print second
print first

Selection by Syntactic Structure of the Rule

- Specificity: select **most specific rule** first
- Example:
  - Conflict set: {R1,R2}
    R1: if A, B, C then <aksi R1>
    R2: if A,C then <aksi R2>
  - A and B and C is more specific than A and C → select R1

Selection by Supplementary Knowledge

Select high priority rule

Example:

R1: If (burung ?X)
then (terbang ya)

R2: If (burung penguin)
(declare salience 100)
then (terbang tidak)

Fakta: (burung penguin)

Meta rules

Pruning rules:

If the culture was not obtained from a sterile source,

there are rules which mention in their premise a previous organism

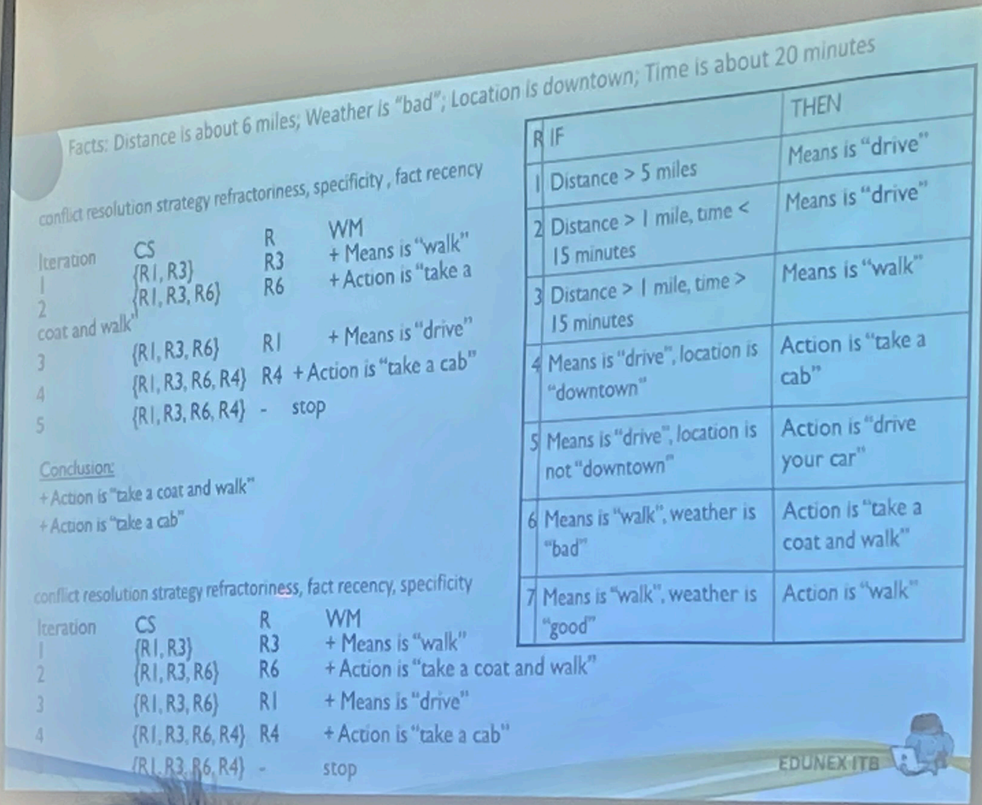
then each of them is not going to be useful

Forward Chaining: Exercise

What action to take to get to a theatre by using conflict resolution strategy refractoriness, specificity ?

Facts: Distance is about 6 miles; Weather is “bad”; Location is downtown; Time is about 20 minutes

R	IF	THEN
1	Distance > 5 miles	Means is “drive”
2	Distance > 1 mile, time < 15 minutes	Means is “drive”
3	Distance > 1 mile, time > 15 minutes	Means is “walk”
4	Means is “drive”, location is “downtown”	Action is “take a cab”
5	Means is “drive”, location is not “downtown”	Action is “drive your car”
6	Means is “walk”, weather is “bad”	Action is “take a coat and walk”
7	Means is “walk”, weather is “good”	Action is “walk”



Facts: Distance is about 6 miles; Weather is "bad"; Location is downtown; Time is about 20 minutes

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6	Means is "walk", weather is "bad"	Action is "take a coat and walk"
7	Means is "walk", weather is "good"	Action is "walk"

conflict resolution strategy refractoriness, specificity , fact recency

Iteration	CS	R	WM
1	{R1, R3}	R3	+ Means is "walk"
2	{R1, R3, R6}	R6	+ Action is "take a coat and walk"
3	{R1, R3, R6}	R1	+ Means is "drive"
4	{R1, R3, R6, R4}	R4	+ Action is "take a cab"
5	{R1, R3, R6, R4}	-	stop

Conclusion:

+ Action is "take a coat and walk"

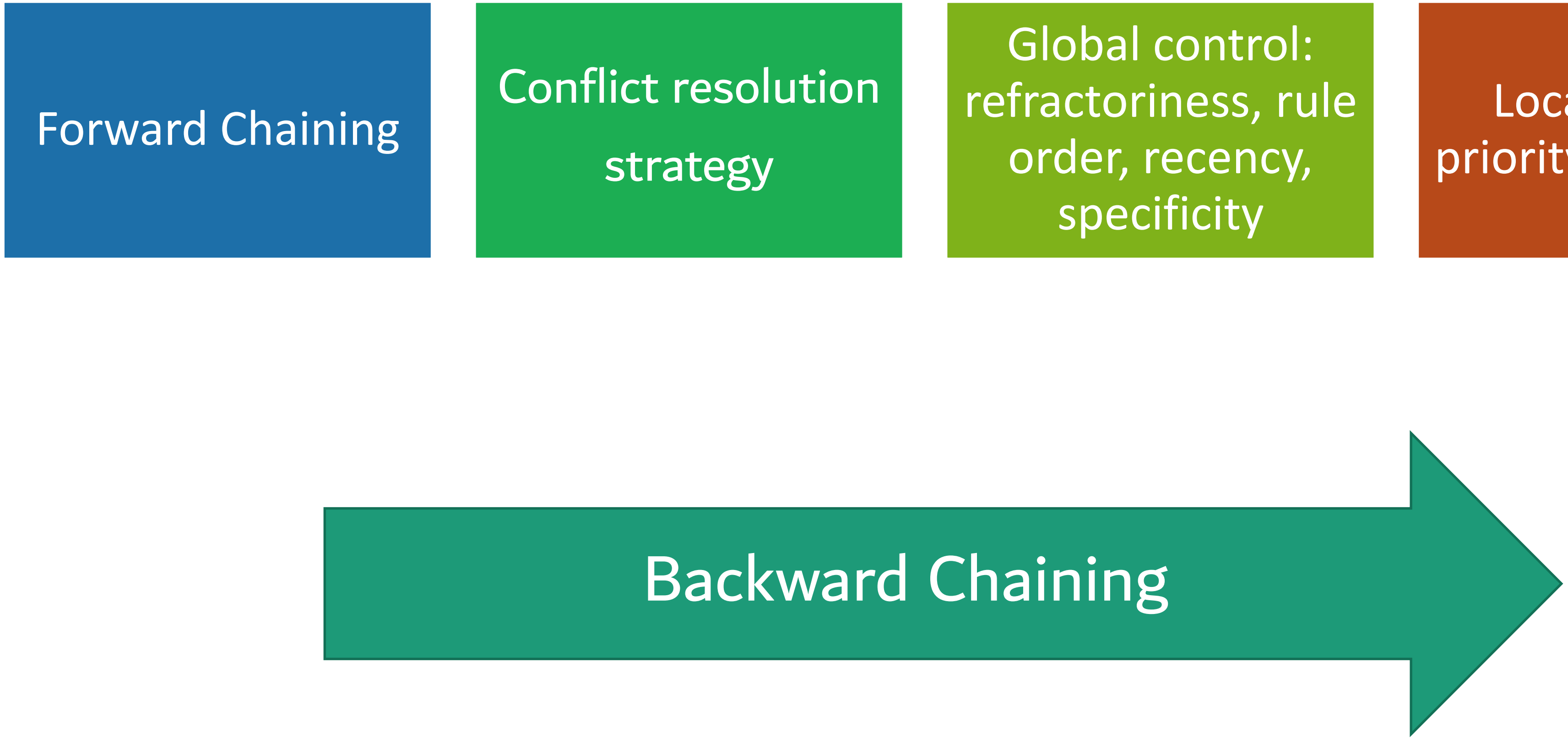
+ Action is "take a cab"

conflict resolution strategy refractoriness, fact recency, specificity

Iteration	CS	R	WM
1	{R1, R3}	R3	+ Means is "walk"
2	{R1, R3, R6}	R6	+ Action is "take a coat and walk"
3	{R1, R3, R6}	R1	+ Means is "drive"
4	{R1, R3, R6, R4}	R4	+ Action is "take a cab"
	{R1, R3, R6, R4}	-	stop

EDUNEX ITB

Summary



Forward Chaining

Conflict resolution strategy

Global control: refractoriness, rule order, recency, specificity

Local control: priority, meta rules

Backward Chaining

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