Rule Based Systems

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Lecture Outline

- Production systems
- Facts & Templates
- Production rules
- The inference process
- Advantages of production systems
- Disadvantages of production systems
- Expert systems

Production Systems

- A production system consists of
  - Working memory (facts memory)
  - Production rules memory
  - Inference engine

Production Systems

- Working memory
  - working memory of the system
  - stores the facts currently being dealt with
  - facts also called *working memory elements*

Production Systems

- Production rules memory
  - stores the set of productions (rules) of the system
  - long term memory of the system

Production Systems

- Inference Engine
  - control mechanism of the system
  - matches facts from working memory with productions
  - selects rules to execute

Facts

- Production rules assess and manipulate *facts*
- Facts are propositions about the objects dealt with by the system
- *Facts* are represented within *templates*

(<object or relation> <attribute_1> <attribute_2>...<attribute_k>)

Templates

- **Examples**
- *(is_a <relationship> <name1><name2>)*
  - a template
- *(is_a father John Mary)*
  - a fact

Templates

- (<car_par><parameter><value>) a template
- (car_par temperature 135) a fact
- (<car_status><system> functioning <status>) a template
- (car_status breaks functioning slowly) a fact
- (car_status cooling functioning overheating) a fact
- (car_status gauge functioning OK) a fact
- (<lecture_attribute><property><value>) a template
- (Presentation is Dull) a fact

Production Rules

- Productions are transformation rules
- Gives one string from another string
  - e.g.,
    - AB -> CD
- Useful for things like compilers, as well as Production Systems

Production Rules

- A production rule consists of two parts
  - left and right
- left side also known as
  - condition
  - antecedent
- right side also known as
  - conclusion
  - action
  - consequent

Production Rules

- Antecedent part of the rule describes the *facts* or *conditions* that must exist for the rule to fire
- Consequent describes
  - the facts that will be established, or
  - the action that will be taken

IF (conditions) THEN (actions)

IF (antecedents) THEN (consequents)

Production Rules

- Condition elements can be:
  - a negation of a fact (means absence of this fact);
- i.e. logical NOT
- e.g. If NOT (sky_is cloudy)
  - expressions with variables or wild cards; a wild card is a variable which can be satisfied by any value; e.g. temperature > 120.

Production Rules

Examples

- IF (Gauge is OK) AND [TEMPERATURE] > 120

  THEN Cooling system is in the state of overheating

- IF (Presentation is Dull) AND (Voice is Monotone)

  THEN Lecture is boring

Production Rules

Examples

- IF (Gauge is OK) AND [TEMPERATURE] < 100

  THEN Cooling system is functioning normally

- IF NOT (Presentation is Dull) AND (Voice is Lively)

  THEN Lecture is Great

The Inference Process

- Antecedent Matching
  - matches facts in working memory against antecedents of rules
  - each combination of facts that satisfies a rule is called an *instantiation*
  - each matching rule is added to the *conflict set* or *agenda*

The Inference Process

- One rule at a time fires
- Rule must be selected from the Agenda
- Some selection strategies:
  - recency
    - triggered by the most recent facts
  - specificity
- rules prioritised by the number of condition elements
  - matches rules with fewer instantiations

The Inference Process

- Rule selection:
  - refraction
    - once a rule has fired, cannot fire again for a period of time
      - certain number of cycles or permanently
  - salience
    - based on priority number attached to each rule
  - random
    - choose a rule at random from the agenda

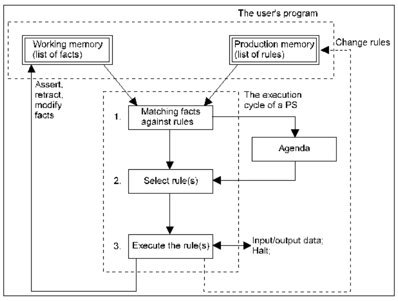
The Inference Process

- Execution of the rule
  - can modify working memory
    - add facts
    - remove facts
    - alter existing facts
  - alter rules
  - perform an external task

The Inference Process

- Inference work repetitively
  - match facts
  - perform inference
  - fire rules
  - modify facts
  - repeat
- continues until no more productions in the agenda

Production System Cycle


The user's program
Working memory (list of facts)
Production memory (list of rules)
Change rules
Assert, retract, modify facts
The execution cycle of a PS
1. Matching facts against rules
Agenda
2. Select rule(s)
3. Execute the rule(s)
Input/output data; Halt;

Advantages

- Universal computational mechanisms
  - can represent any computational process, including a production system
- Universal function approximators
  - can approximate any function given a sufficient number of rules

Advantages

- Intuitive
  - close to how humans articulate knowledge
  - easy to get rules out of a client / user
- Readable
  - rules are easy to read
- Explanatory power
  - can clearly show how a conclusion was reached

Advantages

- Expressive
  - well crafted rules can cover a wide range of situations
  - few rules are needed for some problems
- Modular
  - each rule is a separate piece of knowledge
  - rules can be easily added or deleted

Disadvantages

- Handling uncertainty
  - how to deal with inexact values?
  - if a value is unknown, how to represent it?
  - concepts like *tall*, *short*, *fat*, *thin*
- Sequential
  - one rule at a time fires
  - results can depend on which rule fires first

Disadvantages

- Elucidating the rules
  - how to get the rules in the first place?
  - who wants to write down 5,000 rules?
- Completeness of the rules
  - do the rule cover every possibility?
  - what happens if they don't?

Expert Systems

- Production systems are sometimes called expert systems
- They are not the same thing, however
- An expert system may use a production system, but a production system is not always in an expert system

Expert Systems

- These are information systems for solving a specific problem which provides an expertise similar to those of experts in the problem area.
- An ES contains expert knowledge.

Expert Systems

- A typical ES architecture consists of:
  - knowledge base module;
  - working memory (database) module (for the current data);
  - inference engine
  - user interface (possibly a NLI, menu, GUI, etc.)
  - explanation module

Expert Systems

- Knowledge Base Module
  - stores the domain knowledge
  - analogous to the production rules module of production systems
  - may be production rules
  - may be another model, such as a neural network

Expert Systems

- Working memory
  - same as production systems
- Inference engine
  - controls the functioning of the entire system
  - inference mechanism can be forward or backward chaining

Expert Systems

- Explanation Module
  - explains the reasoning made by the system
  - describes the *HOW* and *WHY* of actions taken
  - HOW it has inferred a fact or conclusion
  - WHY it has taken the action it has

The Inference Process

- Inference can be *forward* or *backward* chaining
- *Chaining* is a line of inference / reasoning
- Forward chaining
  - starts from known facts
  - fires rules to infer a conclusion

The Inference Process

- Backward chaining
  - starts with a conclusion to be proven
  - fires rules that can establish that conclusion

Forward Chaining

- Example:
  - the sky is clear
  - the temperature is warm
  - the wind is light
  - THEREFORE the weather is good
- Good for when the goal is not known by the user

Backward Chaining

- Example:
  - The weather is good
  - THEREFORE
    - is the sky clear?
    - is the temperature warm?
    - is the wind light?
- Goal oriented
- Good for user interaction

Summary

- Production systems are rule based
- Production systems can be universal computational mechanisms and function approximators
- Provide Readable, explainable systems
- Don’t handle uncertainty well

Summary

- Expert systems solve problems in one domain
- Can be based on PS, or other models
- Encapsulate domain knowledge for use
- Problems with acquiring domain knowledge

Questions

- What kind of problem is a Production System suited to?
- What kind of problem would a Production System *not* be suited to?
- How do Expert Systems differ from Production Systems?
- Where would expert systems be more suitable then production systems?