Expert Systems
2020

Boston University

CS 640

Margrit Betke

What is an Expert System?

Expert system =

Knowledge-based system =

Knowledge navigator =

Rule-based system =

Deduction/reaction system =

Recommendation system =

Software agent

Early Successful Expert Systems

Most Famous Industry Products:

- Mavent: Mortgage Loan Advisor checks compliance with Truth-in-lending Act (28 million loan reviews as of 1/2017)
- Mycin: recommended antibiotics
- XCON: eXpert CONfigurer for computer components for DEC VAX

Early Successful Expert Systems

LIMEX: Assessment, irrigation, fertilization, and pest control recommendations to assist lime growers

Many more agricultural expert systems:

- Tomatex (tomatoes)
- Neper Wheat
- Citex (oranges)
- Cupex (cucumbers)

Not so successful Office Assistants

Microsoft’s "Clippit" or "Clippy"

Apple’s bow-tied software assistant: handle calendar, phone calls, discuss rainforest deforestation, etc.

Trend up to recently

Expert Systems based on

- hand-crafted rules and
- search algorithms like
  - Depth-First-Search (DFS) or
  - Bread-First-Search (BFS)

would be replaced by systems based on Machine Learning

State of the Art in 2018

Industrial Research has focused on Predictive Medicine with Machine Learning:

- DeepMind Technologies: Analysis of eye scans, searching for early signs of diseases leading to blindness (2016)
- Soma Logic Inc.: Heart attack prediction via analysis of blood proteins (2016)
- Myriad Genetics Inc.: Molecular diagnostics to predict hereditary cancer risk (2015)

Break-through product

Medial EarlySign

- Medi=medical, al=algorithm
- Company founded by Kalkstein 2009

ML software trained on 2 million records, identifies 10x normal risk of colon cancer from blood test

Used by U.S. Kaiser Permanente HMO & second largest Israeli health care provider

References

- Various wiki pages (see links on course page)
- Bloomberg Business Week, January 15, 2018

Research Trend in 2020

- Early, rule-based approaches to expert systems need to be understood to develop a new-generation expert system
- Pure data-based (statistical) machine learning may not be the answer
- Recent research trend: Combination of rule-based systems and knowledge bases (domain knowledge) with statistical machine learning systems

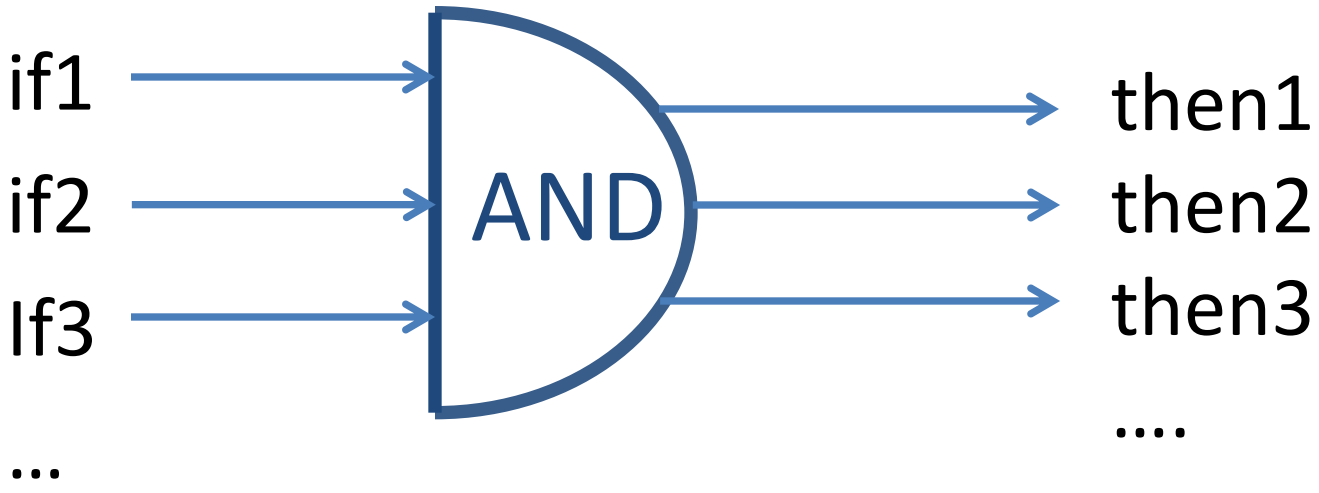
Types of Expert Systems, Rule Syntax

Rule-based Deduction Systems
Reaction Systems

Rule Syntax:

R_n : IF if1 — antecedents
if2
…
THEN then1 — consequents
then2
then3
…

Circuit Visualization



Terminology

- Antecedent = assertion
- Consequent = assertion in deduction system
  = reaction in reaction systems

Fact = something true (never false)

Assertion = statement that something is true
(can be false)

e.g. “It is raining today”

“It is sunny today, 9/10/2020” T or F?

Terminology

"Working Memory" = collection of assertions

"Forward Chaining" = moving from IF to THEN:

IF *all antecedents of R satisfied*

THEN *rule is "triggered"* or

action is "fired"

Example: Zookeeper

- Deduction system to identify animals in a zoo
- Reference: Patrick Winston's AI book
- 7 animals:

  Cheetah, tiger, giraffe, zebra, ostrich, penguin, albatross

<u>1st idea: Build a rule for each type of animal:</u>

R_n : IF *all characteristics of an animal*
THEN *This is animal of type n*

=> 7 rules with long list of antecedents

Zookeeper Expert System

2nd idea:

- Reduce number of antecedents by checking common characteristics
- Produce intermediate assertions
- Compute chains of conclusions

Z1: IF *?x has hair*

THEN *?x is a mammal*

?x is a variable

More Terminology

- If the assertion “Stretch has hair” is in the working memory, variable x can be bound to Stretch
- We also say “Stretch is the binding of x”
- If all variable in the antecedent are bound, the rule is instantiated

Zookeeper Rules

Z1: IF ?x has hair

THEN ?x is a mammal

Z2: IF ?x gives milk

THEN ?x is a mammal

Z3: IF ?x has feathers

THEN ?x is a bird

Forward Chaining Procedure

- Until no rule produces a new assertion,
  - For each rule,
    - For each set of possible variable bindings determined by matching the antecedents to working memory,
      - Instantiate the consequent.
      - Determine whether the instantiated consequent is already asserted. If it is not, assert it.

Backward Chaining Procedure

- Find a rule whose consequent matches the hypothesis and create a binding set
- Try to support each of the rule's antecedents by matching it to assertions in the working memory or by backward chaining through another rule, creating new hypotheses. Be sure to check all matching and instantiation alternatives.
- If all the rule's antecedents are supported, announce success and conclude that the hypothesis is true.

Circuit Visualization for Backward Chaining

Working Memory:

Swifty has hair

Swifty has pointed teeth

Swifty has claws

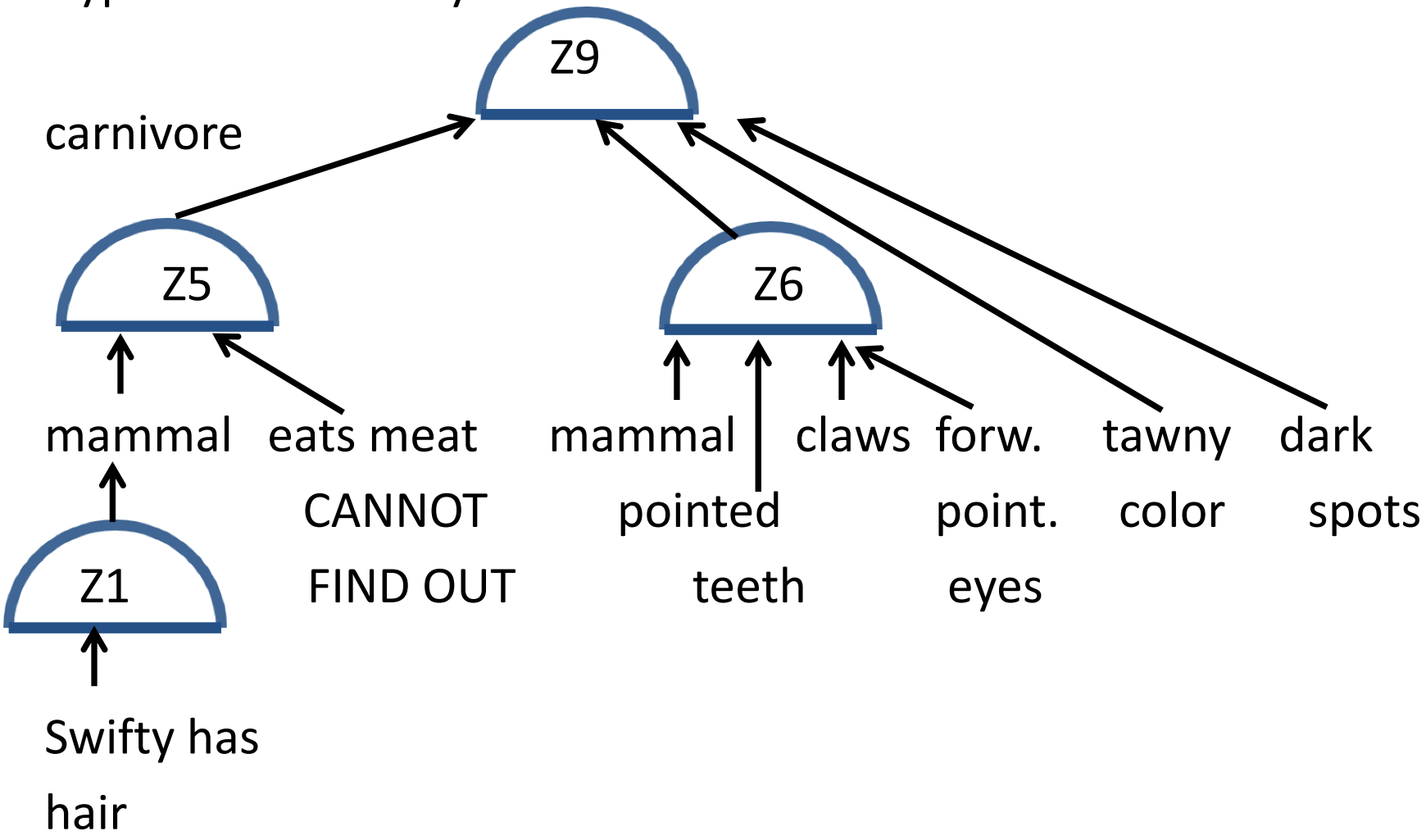
Swifty has forward pointing eyes

Swifty has tawny color

Swifty has dark spots

Hypothesis: “Swifty is a cheetah”

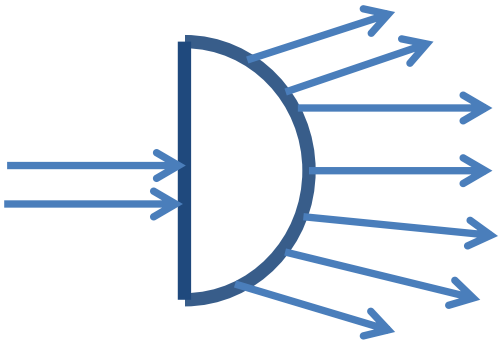
Circuit Visualization for Backward Chaining



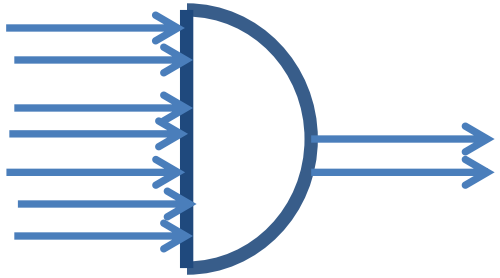
Forward vs. Backward Chaining

- More detailed pseudocode on course webpage
- Which direction is better?

Fan-in << Fan-out



Fan-in >> Fan-out



Forward vs. Backward Chaining

Similar fan-in and fan-out:

Backward chaining if

- Interested in only one of many possible conclusions
- Interested in only a general conclusion ("carnivore")
- Facts not gathered yet, only gather useful facts

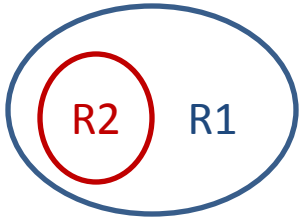
Forward chaining if

- Animal disappeared, cannot gather new facts

Conflict Resolution Strategies

Rule ordering based on:

- **Priority list** (e.g., Bagger)
- **Context**: Groups of rules, only one group active at any time
- **Specificity**: Conditions of R1 & R2: Use R1



- **Data**: Prioritize assertions, use triggered rule with highest priority assertion in conditions list
- **Size**: Use triggered rule with longest list of conditions
- **Recency**: Use least recently used rule

Bagger – A Rule-based Reaction System that Creates a Plan

Design choices:

1. Check-order step
2. Bag-large-items step
3. Bag-medium-items step
4. Bag-small-items step

13 rules (see course website)

Working Memory contains:

- Current Step is check-order.
- Bat 1 is bag.
- Bread (medium item) is to be bagged.
- Glop (small item) is to be bagged.
- Granola (large item) is to be bagged.
- Ice cream (medium, frozen) is to be bagged.
- Potato chips (medium) are to be bagged.

Example Bagging Plan

Plan: B1, B2, B3, B4, B6, B7, B9, B8, B8, B8, B10

<u>Current Working Memory:</u>

Current-step = bag-small-items

Bag 1: Pepsi, Granola

Bag 2: Bread, Ice cream (in freezer bag), potato chips

Glop to be bagged

Final Plan

Plan: B1, B2, B3, B4, B6, B7, B9, B8, B8, B8, B10, B12, B11, B13

Final Working Memory:

Current-step = done

Bag 1: Pepsi, Granola

Bag 2: Bread, Ice cream (in freezer bag), potato chips

Bag 3: Glob