CS370

Symbolic Programming
Declarative Programming

LECTURE 17: Machine Learning

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Machine Learning

- Introduction
- Learning concepts from examples
- Learning relational descriptions
- Learning simple if-then rules
- Induction of decision trees
- Learning from noisy data and tree pruning
- Success of learning

Introduction

Forms of Learning

- learning by being told
- learning by discovery
- learning from examples (inductive learning)

Types of task

- diagnosing a patient or a plant disease
- predicting a weather or the biological activity of a new chemical compound
- determining the biological degradability of chemicals

Learning concepts from examples

Concepts as sets

- U: the universal set of objects
- Concept C: a subset of objects in U
- To learn concept C means to learn to recognize objects in C.

Learning concepts from examples

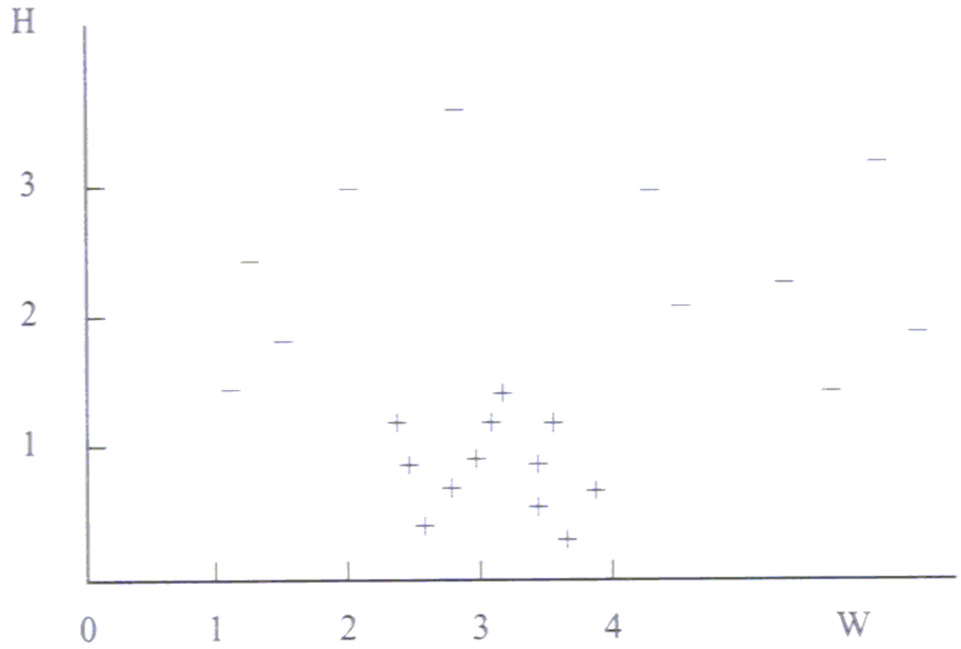
⦿Examples

- the concept of being poisonous
- the concept of an arch
- the concept of multiplication
- the concept of a certain disease

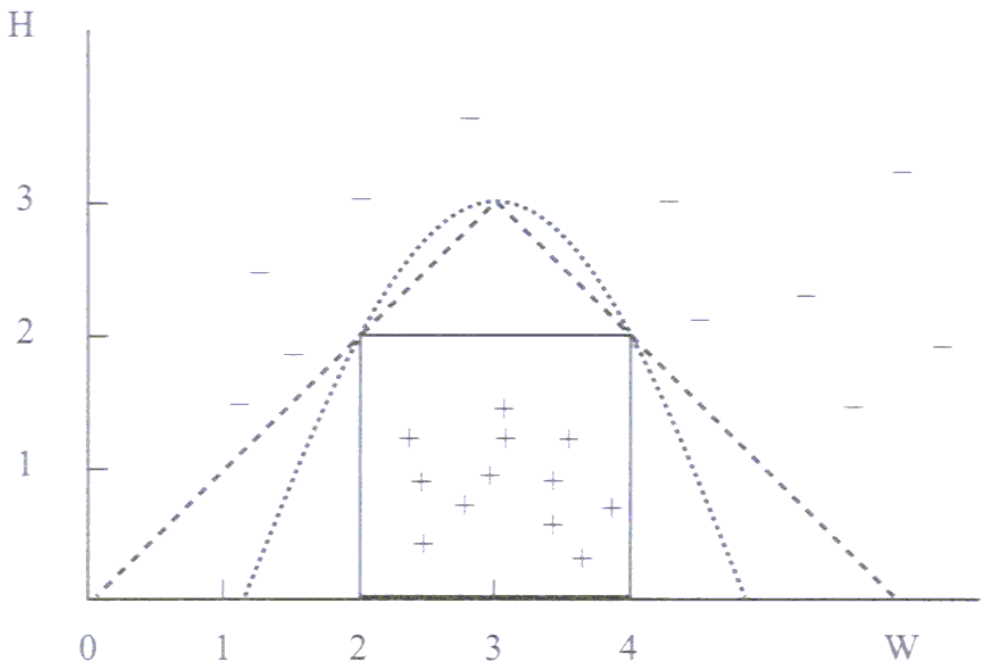
Learning concepts from examples

⦿Examples and hypotheses

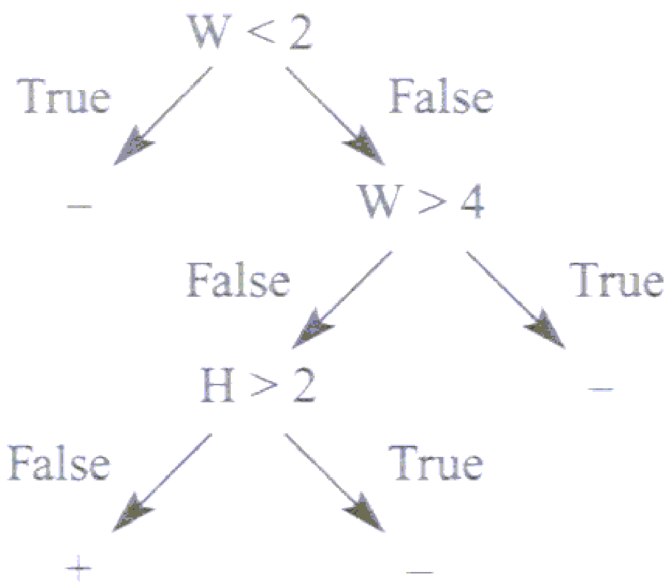
- Pluses for edible, minuses for poisonous



⦿Examples and hypotheses



⦿Examples and hypotheses



Learning concepts from examples

⊙ Description languages for objects and concepts

- relational (structural) descriptions
  - an object is defined in terms of its components and the relations between them
- attribute-value descriptions
  - an object is defined in terms of its global features, or a vector of attribute values

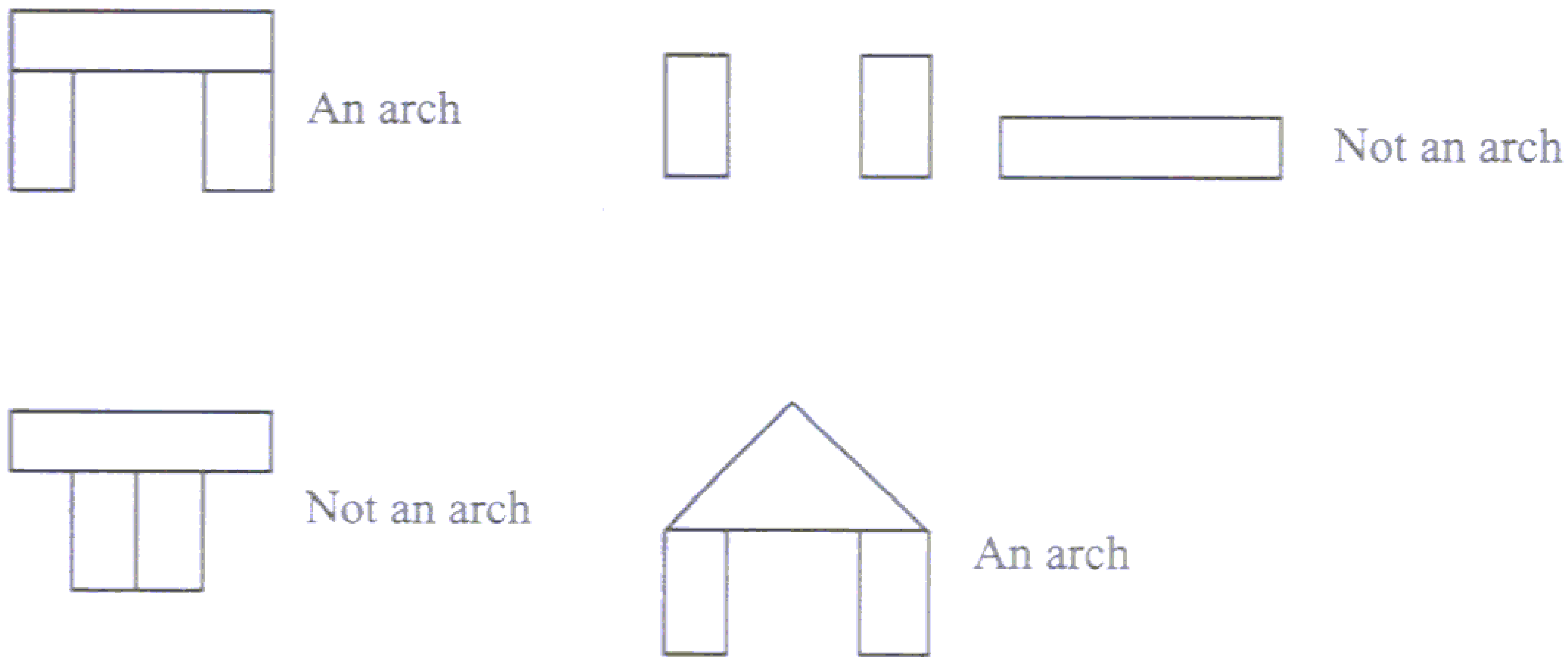
Learning concepts from examples

⊙ Accuracy of hypotheses

- C: target concept
- L: hypothesis language
- S: a set of classified examples (Obj,Class)
- Goal: Find a formula H in L such that H corresponds to C

Learning relational descriptions

⦿the program ARCHES



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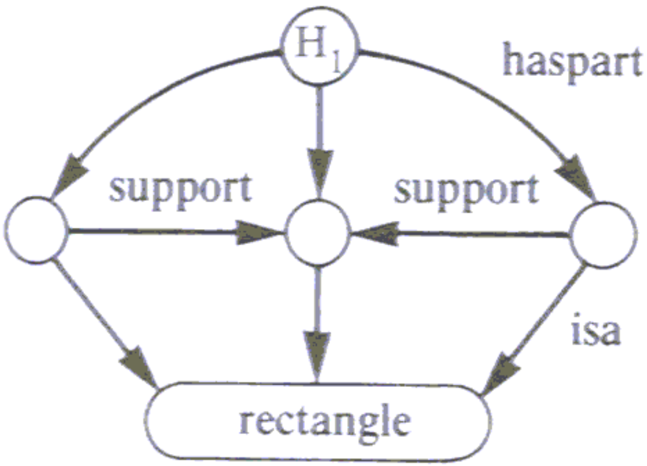

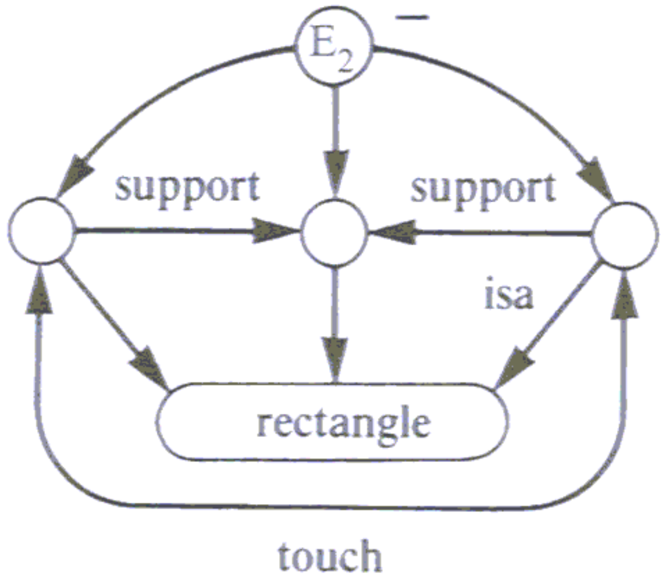

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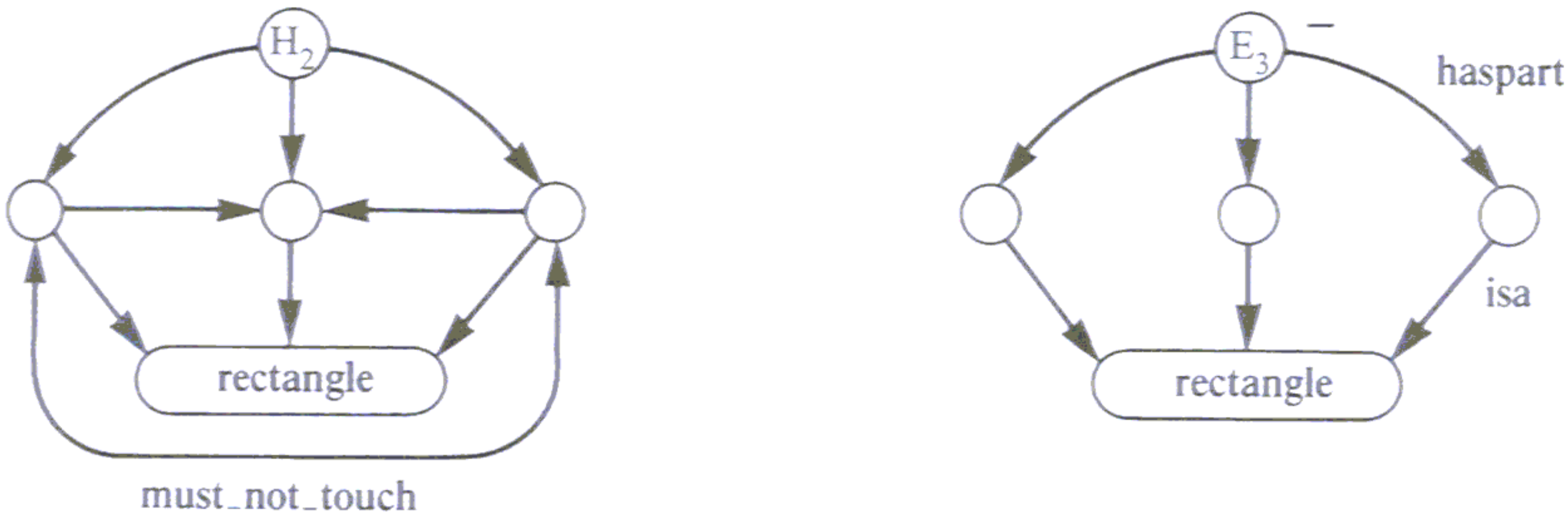
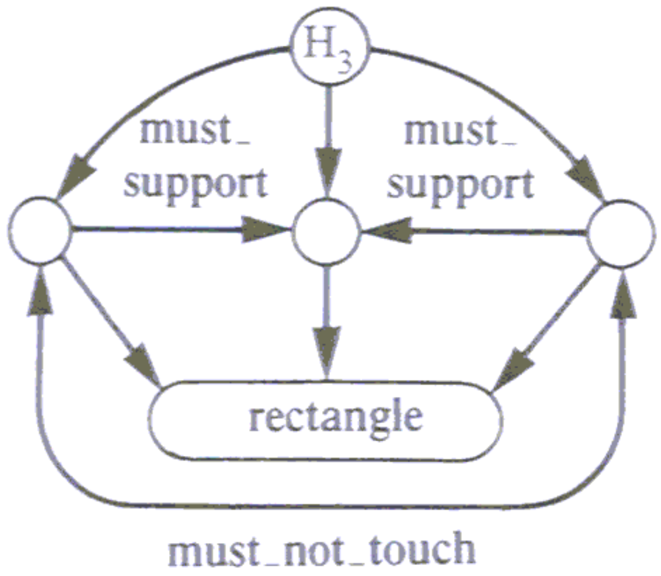
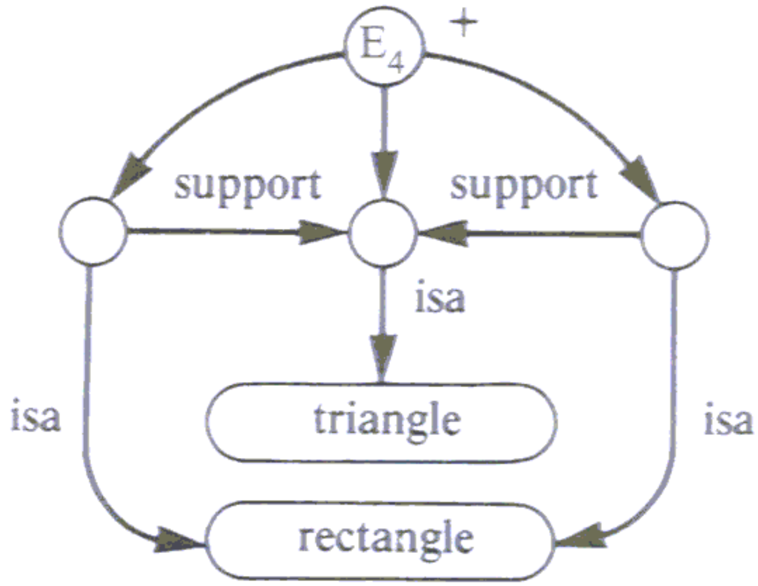


Learning relational descriptions

⦿the program ARCHES





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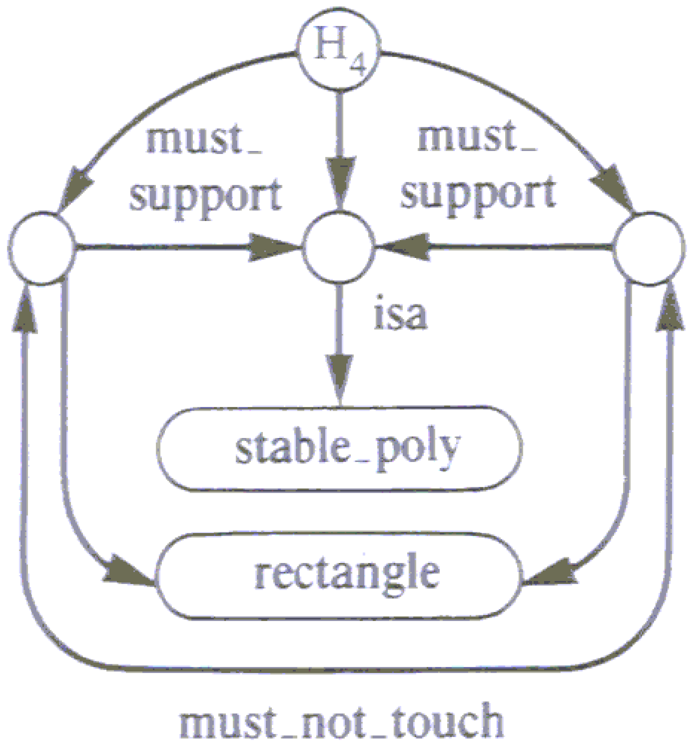
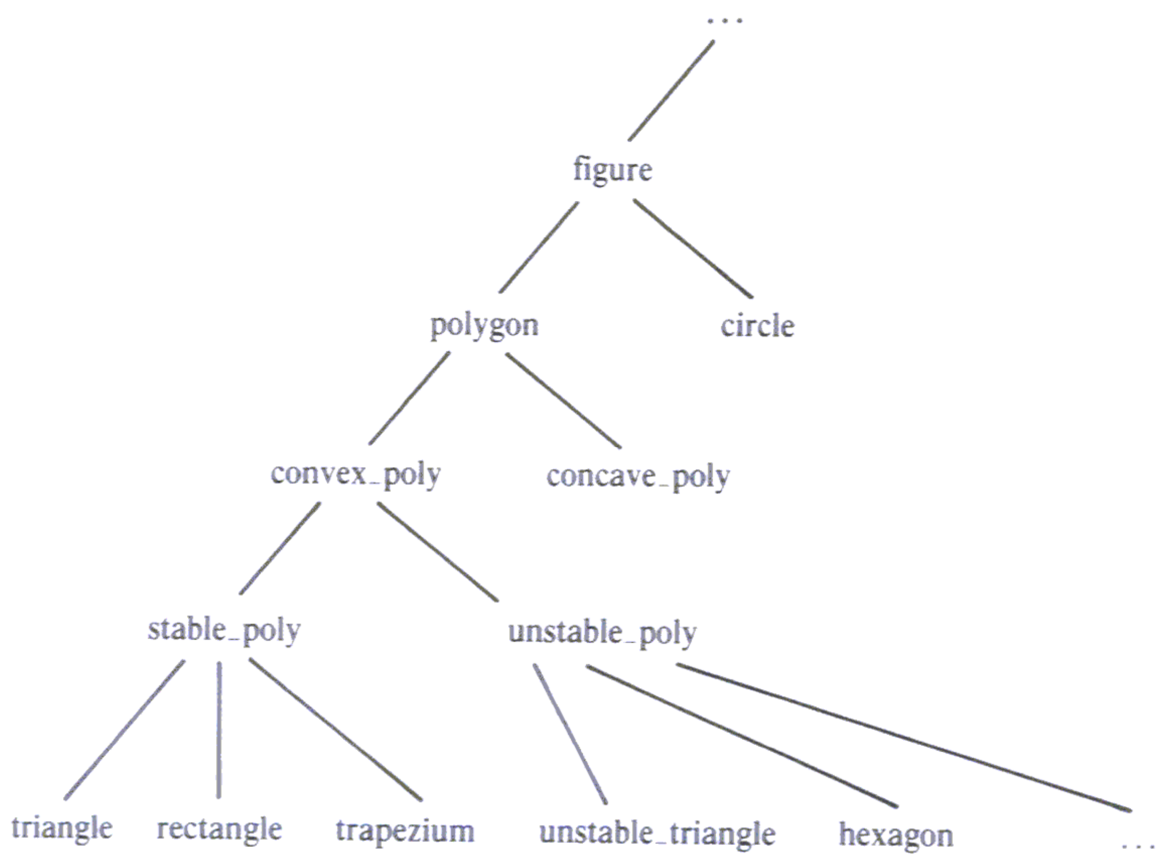
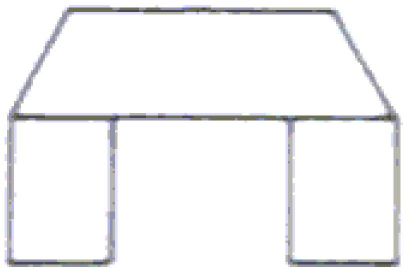
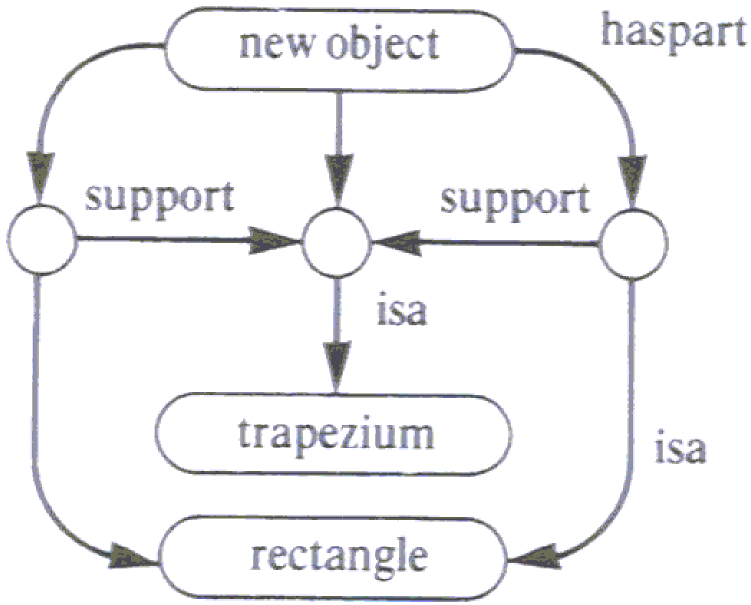


Learning relational descriptions



⊙the program ARCHES





Learning simple if-then rules

- Describing objects and concepts by attributes

Learning simple if-then rules

Describing objects and concepts by attributes

- An object is described by a vector of attribute values.
  - size: small, large
  - shape: long, compact, other
  - holes: none, 1, 2, 3, many

Learning simple if-then rules

- **Describing objects and concepts by attributes**

```
attribute(size,[small,large]).
attribute(shape,[long,compact,other]).
attribute(holes,[none,1,2,3,many]).
. . .
example(nut,[size=small,shape=compact,holes=1]).
. . .
```

Learning simple if-then rules

- **Matching an object and a concept description in Prolog**

```
match(Object,Description) :-
    member(Conjunction,Description),
    satisfy(Object,Conjunction).
satisfy(Object,Conjunction) :-
    not ( member(Att = Val,Conjunction),
          member(Att = ValX,Object),
          ValX \== Val ).
```

Learning simple if-then rules

Inducing rules from examples

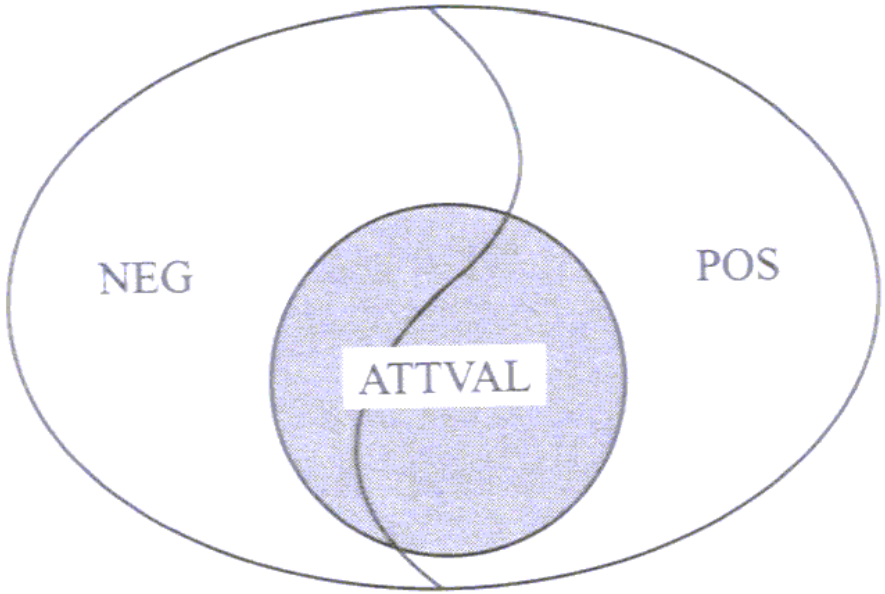
- batch learning (vs incremental learning)
- covering algorithm (Figure 18.11)

```
learn(Class) :-
    bagof(example(ClassX,Obj),
          example(ClassX,Obj),
          Examples),
    learn(Examples,Class,Description),
    nl, write(Class), write('<=='), nl,
    writelist(Description),
    assert(Class<==Description).
```

Learning simple if-then rules

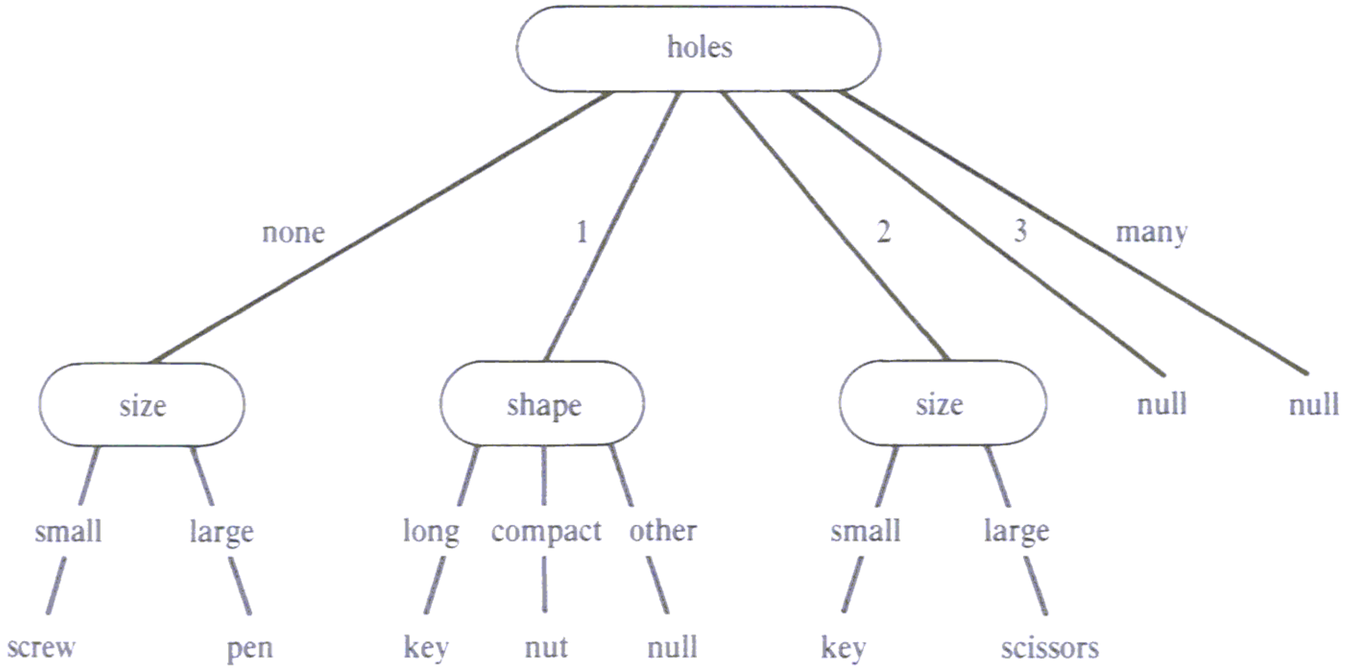
⦿ Heuristic scoring of an attribute value

score(Examples, Class, AttributeValue, Score)



The heuristic score of the attribute value is the # of positive examples in ATTVAL minus the # of negative examples in ATTVAL.

⊙ Induced decision tree: An example



Learning from noisy data and tree pruning

noise in learning

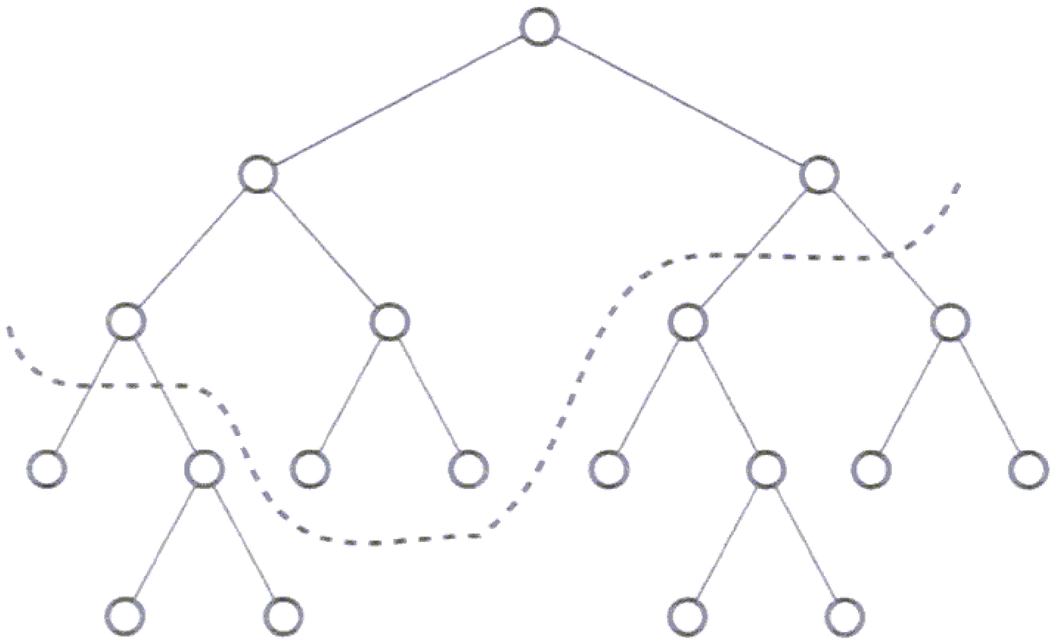
- errors in attribute values and class values

tree pruning

- take into account
  - the number of examples in the node
  - the prevalence of the majority class at the node
  - to what extent an additional attribute selected at this node would reduce the impurity of the example set
- to decide whether to stop expanding the tree or not
- forward pruning and post-pruning

Learning from noisy data and tree pruning

⦿ Pruning of decision trees



Success of learning

⦿Criteria for success of learning

- classification accuracy
  - accuracy on new objects
  - accuracy on the objects in S
- comprehensibility (understandability)
- computational complexity
  - generation complexity
  - execution complexity

Summary

- Learning concepts from examples
- Learning relational descriptions
- Learning simple if-then rules
- Induction of decision trees
- Learning from noisy data and tree pruning
- Success of learning