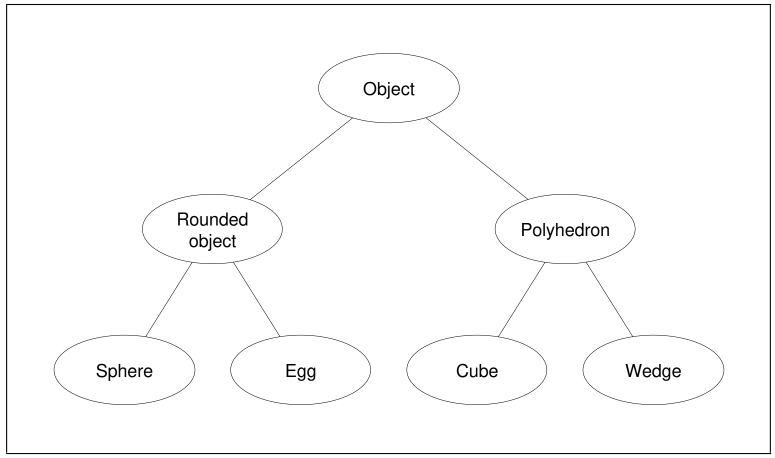


Figure E16.1 A classification tree for shapes.

CHAPTER 16 Learning by Analyzing Differences

Exercise 16.1

Suppose that you want to teach a Martian about ostriches. You show it an ostrich that is tall and that has a long neck, long legs, and black feathers. Next, you select negative examples from a group that includes a penguin, a tall black crane, a crow, an elephant, a giraffe, a gazelle, and a kiwi.

You want to convey the idea that ostriches cannot fly. Which animal should you use? What heuristic should the Martian deduce in response?

Solution 16.1

Show the Martian a tall black crane. Like the ostrich example, it is tall and it has a long neck, long legs, and black feathers, but it flies. The Martian would respond using the forbid-link heuristic.

Exercise 16.2

You want to teach a Martian about apples. You assume that the Martian's perceptual system builds semantic nets with only the following information in them:

- An object's color is red, green, blue, purple, white, or black.
- An object's weight is a number.
- An object's shape is any one of those in the tree shown in figure E16.1.
- An object may be inedible, fragrant, or smelly. There are no other properties that an object may have.

You elect the following teaching sequence. For each example, note what heuristic is applied and explain what is learned.

Example	Result	Color	Shape	Weight	Quality
1	positive	red	sphere	4	fragrant
2	positive	red	sphere	4	
3	negative	red	sphere	4	inedible
4	positive	green	sphere	4	
5	positive	green	sphere	7	
6	positive	red	egg	5	
7	negative	red	cube	4	

Solution 16.2

Example	Heuristic	Result
1	—	One apple is a red fragrant sphere with weight 4
2	Drop link	Apples do not need to be fragrant
3	Forbid link	Apples must not be inedible
4	Enlarge set	Apples must be red or green
5	Close interval	Apple weights range from 4 to 7
6	Climb tree	Apples must be round
7	—	Nothing new

Exercise 16.3

Solution 16.3

Exercise 16.4

Solution 16.4

Exercise 16.5

You decide you have had it with computer science; you earn a degree in medicine instead. As a junior resident in a university hospital, you are asked by a department head to study a patient who has a mysterious allergy.

You somehow feel absolutely sure that the allergic reaction is caused by the patient's eating a combination of certain foods over the course of a day. For example, the allergic reaction may be caused by eating apples, eggs, fish, *and* honey during the same day.

Accordingly, you ask the one and only patient with the allergy to write down what he eats every day, and to indicate whether he has an allergic reaction on that day. During 7 days, the patient produces the following data:

Day	Apples	Beef	Cake	Dates	Eggs	Fish	Grapes	Honey	Reaction
1	yes	no	yes	yes	yes	yes	yes	yes	yes
2	no	no	yes	yes	yes	yes	no	no	no
3	yes	no	yes	yes	yes	no	yes	no	yes
4	yes	no	yes	no	no	no	no	no	no
5	yes	no	yes	yes	yes	yes	no	yes	yes
6	yes	yes	no	yes	yes	yes	no	no	no
7	no	yes	no	yes	yes	yes	no	no	no

Part 1 From the positive examples, determine which foods could be involved. Then, using the negative examples and the near-miss idea, determine which foods you can proscribe such that the patient absolutely will not have an allergic reaction if he avoids at least one food from the proscribed group every day.

Part 2 Now suppose that your patient misunderstands your instructions and writes down what he eats on only those days (1, 3, and 5) when he has an allergic reaction. What food or combination of foods would you proscribe such that the patient absolutely will not become allergic, yet is minimally constrained in the face of the data.

Part 3 Explain whether more data will help you to reduce the constraints placed on the patient, given that the patient continues to record what he has eaten only when he has an allergic reaction and that the patient decides whether to eat each food on each day by flipping a coin.

Part 4 Now, suppose you change your mind. You feel absolutely sure that the allergic reaction is caused by the patient's eating any one of certain foods over the course of a day. For example, the allergic reaction may be caused by eating apples *or* eggs *or* fish *or* honey.

From the data, determine which foods could be involved. Then, using the near-miss idea, determine which foods you can proscribe such that the patient absolutely will not have an allergic reaction if he avoids all of them every day.

Solution 16.5

Part 1 Consider the following table, which contains only reaction cases:

Day	Apples	Beef	Cake	Dates	Eggs	Fish	Grapes	Honey	Reaction
1	yes	no	yes	yes	yes	yes	yes	yes	yes
3	yes	no	yes	yes	yes	no	yes	no	yes
5	yes	no	yes	yes	yes	yes	no	yes	yes

Evidently, the patient has a reaction on days when he eats apples, cake, dates, and eggs. Some subset of these foods, or perhaps all of them, eaten together, must cause the reaction.

Near-miss analysis does the rest. Plainly, apples are implicated because, on day 2, the patient eats cake, dates, and eggs, but no apples, and has no reaction. Similarly, cake is implicated because, on day 6, the patient eats apples, dates, and eggs, but no cake, and has no reaction. Finally, either dates or eggs are implicated because, on day 4, the patient eats apples and cake, but neither dates or eggs, and has no reaction. You cannot, however, nail down for sure which of dates or eggs, if either, he can avoid and be safe.

Thus, you should tell the patient to avoid at least one of apples and cake.

Part 2 The loss of negative examples does a great deal of damage because you cannot distinguish between foods that cause the reaction and foods that happen to be eaten on days when the reaction occurs.

You can only tell the patient that he must not eat any of the four foods that were eaten on reaction days. That is, he must not eat apples or cake or dates or eggs.

Part 3 More data will help, because it becomes increasingly unlikely that the patient will always have eaten an irrelevant food on a reaction day. Eventually, with a vanishingly small probability of failure, you can advise the patient that he can avoid a reaction by avoiding any one of the foods that always appear.

Part 4 Now you need to concentrate on the foods that are never eaten on no-reaction days. Consider the following table, which contains only no-reaction cases:

Day	Apples	Beef	Cake	Dates	Eggs	Fish	Grapes	Honey	Reaction
2	no	no	yes	yes	yes	yes	no	no	no
4	yes	no	yes	no	no	no	no	no	no
6	yes	yes	no	yes	yes	yes	no	no	no
7	no	yes	no	yes	yes	yes	no	no	no

Evidently, only grapes and honey are not eaten on no reaction days. One of these, or perhaps either, causes the reaction.

Near-miss analysis does the rest. On the third day, the patient eats grapes but no honey, and has a reaction. On the fifth day, he eats honey but no grapes, and has a reaction. Evidently, eating either causes the reaction.

Exercise 16.6

Solution 16.6

CHAPTER 20 Learning by Managing Multiple Models

Exercise 20.1

Solution 20.1

Exercise 20.2

Solution 20.2

Exercise 20.3

Explain why a sample that matches all specific models is guaranteed to be a positive sample. In particular, explain why you can be sure that [Sam's Dinner Wednesday Cheap] is a positive sample once you have analyzed [Sam's Breakfast Friday Cheap] and [Sam's Lunch Saturday Cheap].

Solution 20.3

If a combination of attributes matches all the specific models, it must be a positive sample, because none of the specific models can ever become more specific. Hence, the combination of attributes must continue to match everything into which the specific models evolve.

Thus, you can be sure that [Sam's Dinner Wednesday Cheap] must be a positive sample, once you have analyzed [Sam's Breakfast Friday Cheap] and [Sam's Lunch Saturday Cheap], because the one and only specific model, [Sam's ? ? Cheap], matches [Sam's Dinner Wednesday Cheap].

Exercise 20.4

Solution 20.4

Exercise 20.5

Suppose that the days of the week are arranged in a class hierarchy that distinguishes between workdays and weekend days, as shown in figure E20.1.

How would this class hierarchy affect specialization and generalization operations in the allergy example?

Solution 20.5

If the days of the week are arranged in a class hierarchy that distinguishes between workdays and weekend days, specialization on the day attribute may be from [– – ? –] to [– – Workday –] or [– – Weekend –], rather than to a specific day of the week. Of course, further specialization of either [– – Workday –] or [– – Weekend –] specializes to a specific day.

Similarly, generalization of a specific day may be to [– – Workday –] or [– – Weekend –], rather than to [– – ? –]. And both [– – Workday –] and [– – Weekend –] generalize to [– – ? –].

Exercise 20.6

Show the development of a version space for the allergy example, given that days are divided into workdays and weekend days.

Solution 20.6

The development of a version space for the allergy example, given that days are divided into workdays and weekend days, proceeds exactly as before.

The reason is that generalizing [Sam's Breakfast Friday Cheap], given the positive example [Sam's Lunch Saturday Cheap], forces you to climb the class hierarchy all the way up to the question-mark level. After that, specialization of a general model can never introduce a workday or weekend-day symbol, because all general models must be more general than the specific model.

Exercise 20.7

Suppose that the class hierarchy is expanded to include the notion of a long-weekend day; see figure E20.2.

Further suppose that the sequence of samples is the same as before, except for some changes in the day attribute:

Number	Restaurant	Meal	Day	Cost	Reaction?
1	Sam's	breakfast	Saturday	cheap	yes
2	Lobdell	lunch	Saturday	expensive	no
3	Sam's	lunch	Sunday	cheap	yes
4	Sarah's	breakfast	Monday	cheap	no
5	Sam's	breakfast	Sunday	expensive	no

Show how the version-space procedure would handle the samples.

Figure E20.1 A class hierarchy for the days of the week.

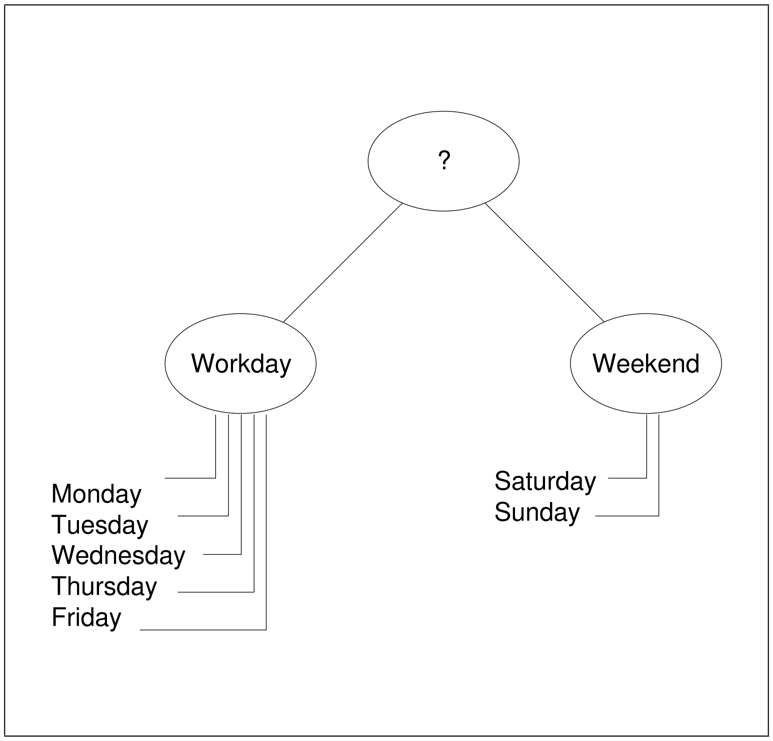
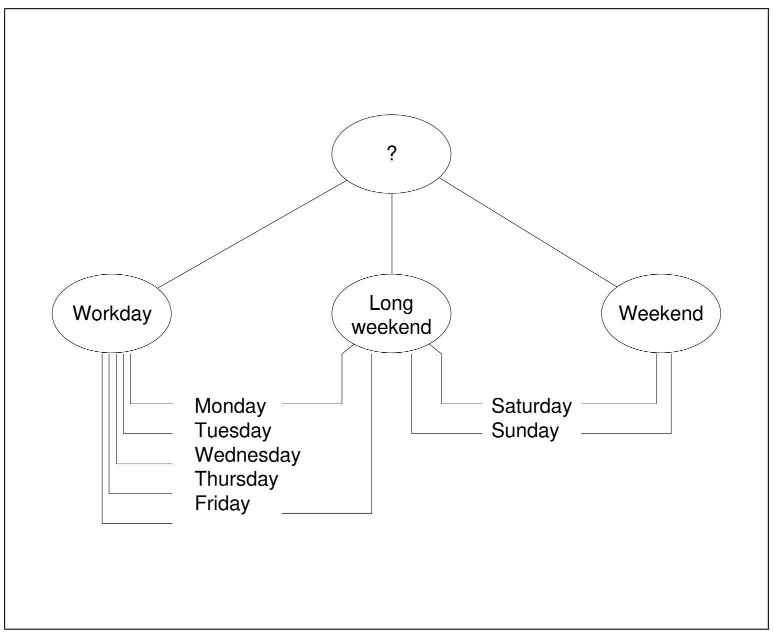


Figure E20.2 A class hierarchy for the days of the week, augmented with the long-weekend class.



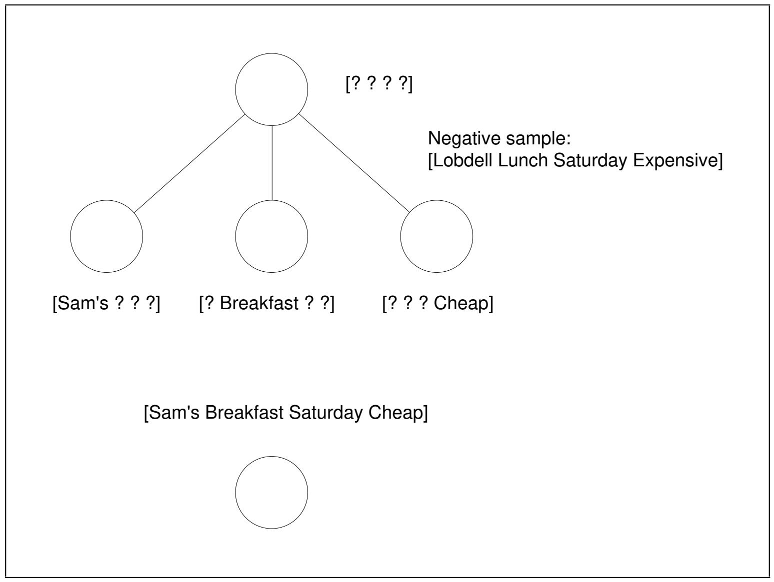


Figure S20.1 The evolution of a version space in which there are multiple generalizations.

Solution 20.7

The version-space evolution, given the incorporation of the notion of a long-weekend day, is as shown in figure S20.1. Note, in particular, that the solution provides, at last, an example of a specific model producing more than one new generalization. Also note that the version space has yet to converge on a single model.

Figure S20.1 Continued.

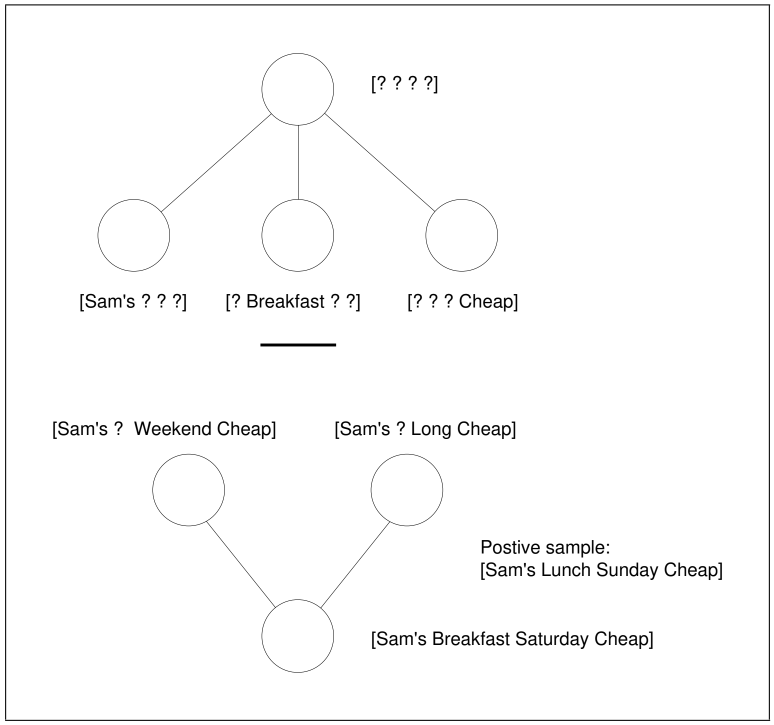


Figure S20.1 Continued.

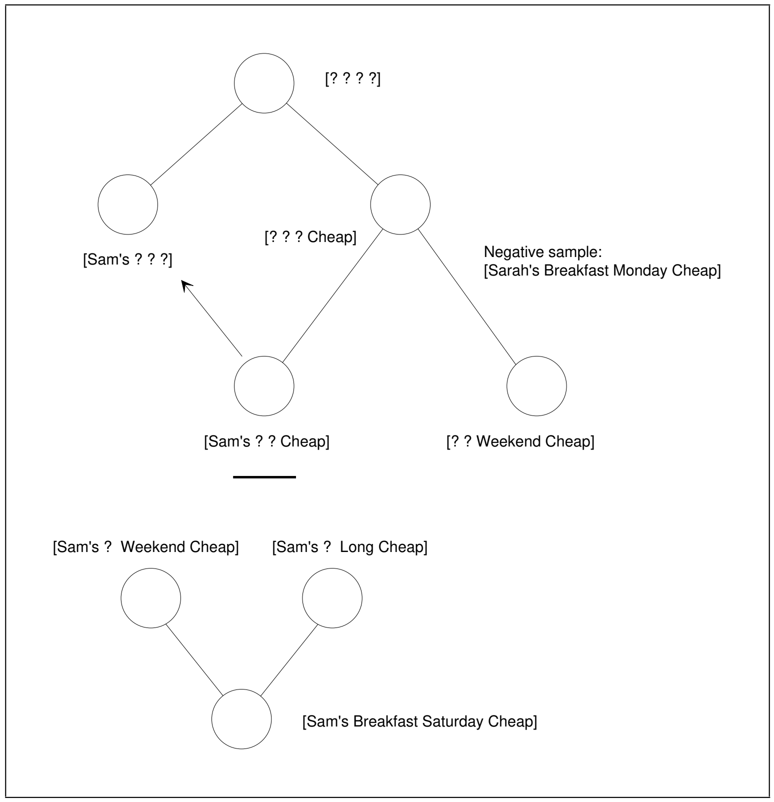


Figure S20.1 Continued.