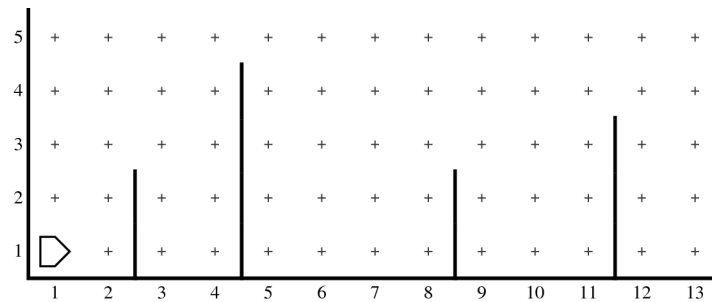# An Example of Stepwise Refinement

For those who are not fortunate enough to live in all-year-round sunny weather like Ethiopia, winter maintains a solid hold on the world. The trees have lost their leaves and stand as empty monuments to the ravages of the season. And, even here, the recent rain has us longing for spring.

In this sample world, the vertical wall sections represent barren tree trunks. In an attempt to add some semblance of life back to the world, Karel has taken on the mission of adorning the barren trees with a new set of leaves represented by beepers. Karel's plan is to climb each of the trees and adorn the top of each tree with a cluster of four leaves arranged in a square like this:

Thus, when Karel is done, the scene will look like this:

As in most Karel problems, the situation that Karel faces need not match exactly the one shown in the diagram. There may be more trees; Karel simply continues the process until there are no beepers left in the beeper bag. The trees may also be of different heights or spaced differently than the ones shown in the diagram. Your task is to design a program that is general enough to solve any such problem, subject to the following assumptions:

- Karel starts at the origin facing east, somewhere west of the first tree.
- The trees are always separated by at least two corners, so that the leaves at the top don't interfere with one another.
- The trees always end at least two corners below the top, so that the leaf cluster will not run into the top wall.
- Karel has exactly enough beepers to outfit all the trees. The original number of beepers must therefore be four times the number of trees.
- Karel should finish facing east at the bottom of the last tree.

Think hard about what the parts of this program are and how you could break it down into simpler subproblems. What if there were only one tree? How does that simplify the problem, and how can you use the one-tree solution to help solve the more general case?

The solutions will be available on the website as Reading #4A.

Stepwise Refinement

Stepwise Refinement

- The most effective way to solve a complex problem is to break it down into successively simpler subproblems.
- You start by breaking the whole task down into simpler parts.
- Some of those tasks may themselves need subdivision.
- This process is called *stepwise refinement* or *decomposition*.
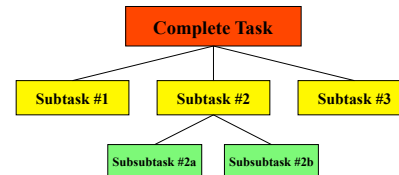
Criteria for Choosing a Decomposition

1. ***The proposed steps should be easy to explain.*** One indication that you have succeeded is being able to find simple names.

2. ***The steps should be as general as possible.*** Programming tools get reused all the time. If your methods perform general tasks, they are much easier to reuse.

3. ***The steps should make sense at the level of abstraction at which they are used.*** If you have a method that does the right job but whose name doesn't make sense in the context of the problem, it is probably worth defining a new method that calls the old one.

Exercise: Banishing Winter

- In this problem (which is described in detail in Handout #4), Karel is supposed to usher in springtime by placing bundles of leaves at the top of each "tree" in the world.
- One of the first things you need to do given a problem of this sort is to make sure you understand all the details.
- According to the handout, Karel stops when it runs out of beepers. Why couldn't it just stop at the end of 1st Street?
- You can break this program down into two tasks that are executed repeatedly:
  - Find the next tree.
  - Decorate that tree with leaves.

Preconditions and Postconditions

- Many of the bugs that you are likely to have come from being careless about the conditions under which you use a particular method.
- As an example, it would be easy to forget the `turnLeft` call at the end of the `addLeavesToTree` method.
- To reduce the likelihood of such errors, it is useful to define pre- and postconditions for every method you write.
  - A *precondition* specifies something that must be true before a method is called.
  - A *postcondition* specifies something that must be true after the method call returns.

Algorithmic Programming in Karel

- In computer science, a well-specified strategy for solving a problem is called an ***algorithm***.
- The goal for the rest of this lecture is to write a program that solves a maze using the ***right-hand rule***: