IS12 - Introduction to Programming

Lecture 3: Program Design

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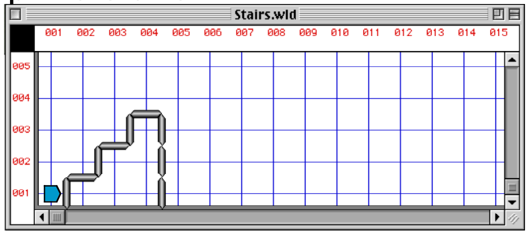
Overview

- Why else do we need new commands
  - Case 2: Up the Stairs
  - Case 3: Sweep the Stairs
- Program design
  - Top-down and design tree approaches
- Exercises in modifying a well-designed program

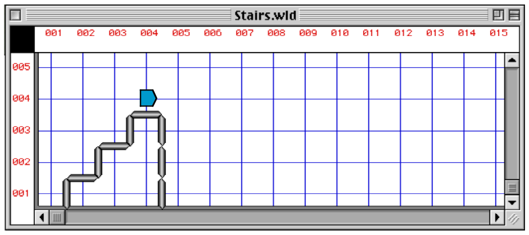
Why? Case 2: Up the Stairs

- Move Karel up the stairs

Start:



Target:

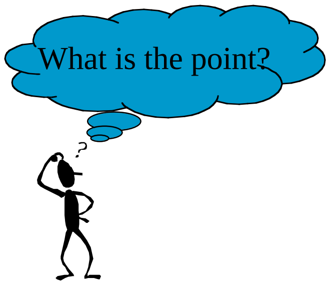


Why? Case 2: Up the Stairs

```
beginning-of-program
   define-new-instruction
   turnright  as begin
        turnleft ;
        turnleft;
        turnleft;
   end;
beginning-of-execution
   turnleft ;
   move;
   turnright ;
   move;
   turnleft ;
   move;
   turnright ;
   move;
   turnleft ;
   move;
   turnright ;
   move;
   turnoff;
end-of-execution
end-of-program
```

Solution 2: Up the Stairs

```
beginning-of-program
   define-new-instruction
   turnright  as begin
        turnleft ;
        turnleft;
        turnleft;
   end;
   define-new-instruction
   climb-stair as begin
        turnleft ;
        move;
        turnright ;
        move;
   end;
```



```
beginning-of-execution
   climb-stair;
   climb-stair;
   climb-stair;
   turnoff;
end-of-execution
end-of-program
```

Walk Around the Block Again

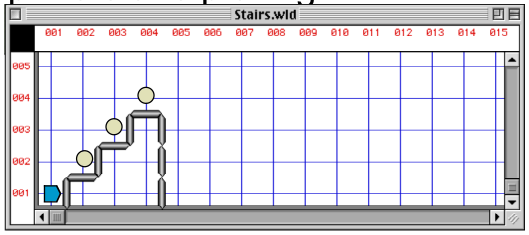
```
beginning-of-program
   define-new-instruction
   turnright  as begin
        turnleft ;
        turnleft;
        turnleft;
   end;
   define-new-instruction
   __________ as begin




   end;
```

```
beginning-of-execution





   turnoff;
end-of-execution
end-of-program
```

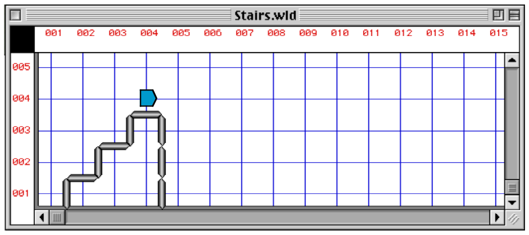
Why? Case 3: Sweep the Stairs

- Move Karel up the stairs picking beepers

Start:



Target:



Solution 3: Sweep the Stairs

```
beginning-of-program
   define-new-instruction
   turnright  as begin
        turnleft;
        turnleft;
        turnleft;
   end;
   define-new-instruction
   climb-stair as begin
        turnleft;
        move;
        turnright;
        move;
   end;
```

```
beginning-of-execution
   climb-stair;
   pickbeeper;
   climb-stair;
   pickbeeper;
   climb-stair;
   pickbeeper;
   turnoff;
end-of-execution
end-of-program
```

What is the point?

Why do we need new instructions?

- Defining clearly missing commands
  - turnright
- Automating repeating fragments
  - climb-stairs
- Creating useful new instructions that can be re-used in several contexts
  - climb-stairs

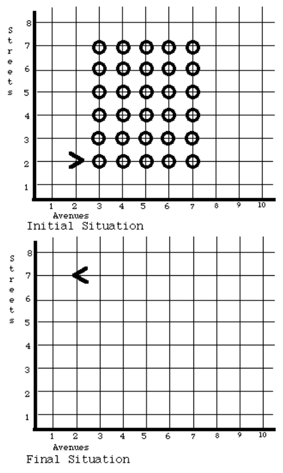
Program Design

- Overall goals:
  - our programs must be easy to read and understand
  - our programs must be easy to debug
  - our programs must be easy to modify to solve variations of the original task
- The approach:
  - Programming as problem solving

How to Solve a Problem

- Polya describes problem solving as a process with four activities
  - definition of the problem
  - planning the solution
  - implementing the plan
  - analyzing the solution
- Implementation is just one of four!
- Planning is the key

Case 1: The Harvest Task



- Karel has to pick up a field of beepers
- We will use a *top-down approach* known as *stepwise refinement*
- Decompose problem into sub-problems
- Write the top-level program using names of new instructions
- Define them later

First Trial with Harvesting a Row

```
beginning-of-execution
   move;
   harvest-1-row;
   return-to-start;
   move-north-1-block;
   harvest-1-row;
   return-to-start;
   move-north-1-block;
   harvest-1-row;
   return-to-start;
   move-north-1-block;
   harvest-1-row;
   return-to-start;
   move-north-1-block;
   harvest-1-row;
   return-to-start;
   move-north-1-block;
   harvest-1-row;
   return-to-start;
   turnoff;
end-of-execution
```

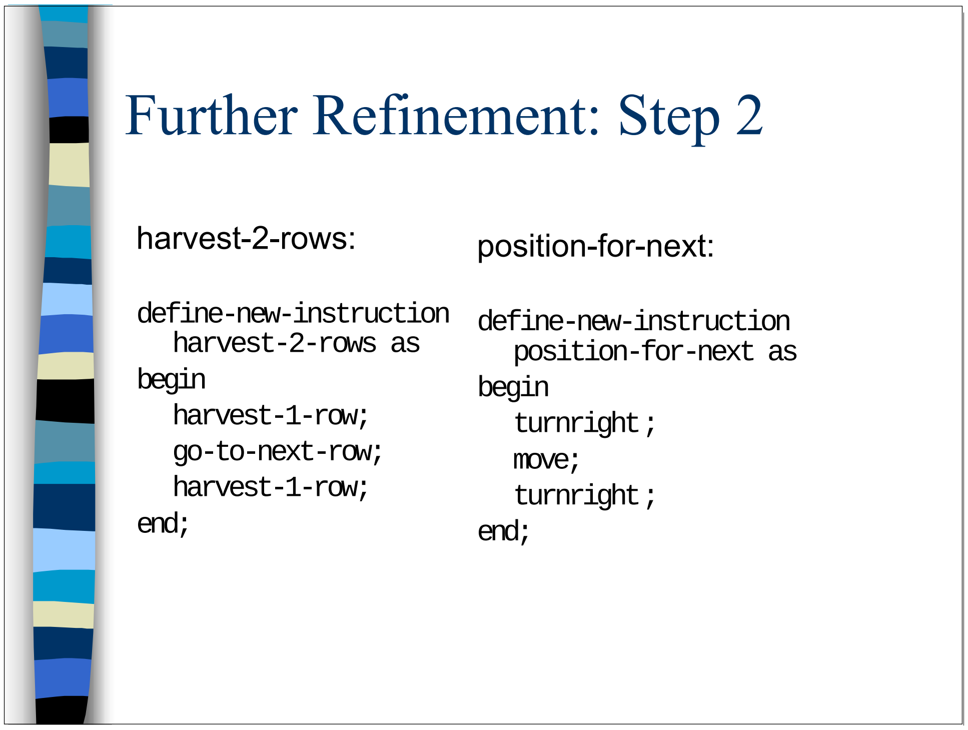
Second Trial: Harvesting 2 Rows

Main program:

```
beginning-of-execution
   move;
   harvest-2-rows;
   position-for-next;
   harvest-2-rows;
   position-for-next;
   harvest-2-rows;
   move;
   turnoff;
end-of-execution
```

Possible implementation of harvest-2-rows

```
define-new-instruction
   harvest-2-rows as
begin
   harvest-1-row-moving-east;
   go-north-to-next-row;
   harvest-1-row-moving-west;
end;
```



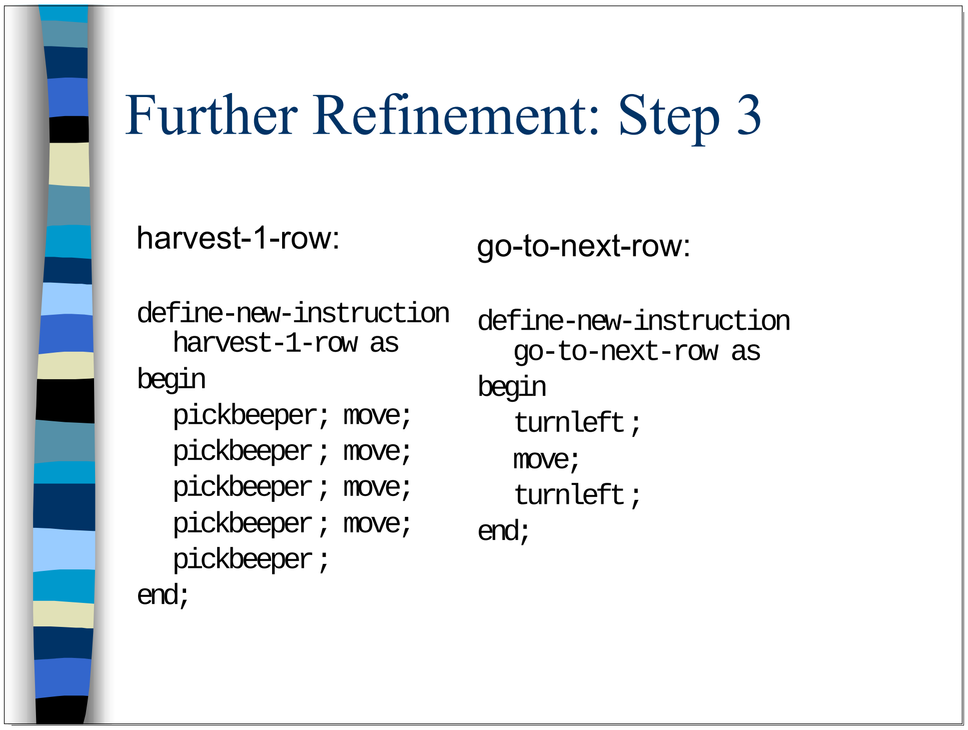
Further Refinement: Step 2

harvest-2-rows:

```
define-new-instruction
   harvest-2-rows as
begin
   harvest-1-row;
   go-to-next-row;
   harvest-1-row;
end;
```

position-for-next:

```
define-new-instruction
   position-for-next as
begin
   turnright;
   move;
   turnright;
end;
```



Further Refinement: Step 3

harvest-1-row:

```
define-new-instruction
   harvest-1-row as
begin
   pickbeeper; move;
   pickbeeper; move;
   pickbeeper; move;
   pickbeeper; move;
   pickbeeper;
end;
```

go-to-next-row:

```
define-new-instruction
   go-to-next-row as
begin
   turnleft;
   move;
   turnleft;
end;
```

Solution for Harvest Problem

```
beginning-of-program
    define-new-instruction turnright
    as begin
           turnleft;
           turnleft;
           turnleft;
    end;
    define-new-instruction
    go-to-next-row as begin
           turnleft;
           move;
           turnleft;
    end;
    define-new-instruction position-
    for-next as begin
           turnright;
           move;
           turnright;
    end;
        define-new-instruction harvest-1-row as
        begin
               pickbeeper; move;
               pickbeeper; move;
               pickbeeper; move;
               pickbeeper; move;
               pickbeeper;
        end;
        define-new-instruction harvest-2-rows
        as begin
               harvest-1-row;
               go-to-next-row;
               harvest-1-row;
        end;
        beginning-of-execution
               move;
               harvest-2-rows;
               position-for-next;
               harvest-2-rows;
               position-for-next;
               harvest-2-rows;
               move;
               turnoff;
        end-of-execution
    end-of-program
```

Stepwise refinement tree for Harvest

$$\begin{tikzcd}
 & & \text{Harvest problem} \arrow[dl] \arrow[dr] & \\
 & \text{harvest-2-rows} \arrow[dl] \arrow[dr] & & \text{position-for-next} \arrow[d] \\
\text{harvest-1-row} & & \text{go-to-next-row} & \text{turnright}
\end{tikzcd}$$

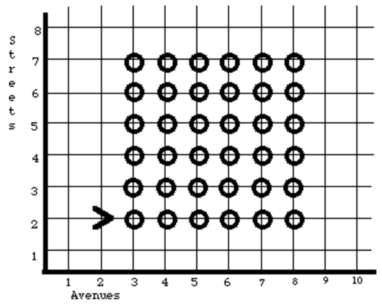
Stepwise Refinement vs. Design Tree Approaches

- Stepwise refinement
    - Breadth first approach
    - Design program down to code
    - Debug components
    - Debug whole
- Design tree
    - Depth first approach
    - Design top level program
    - Get the first slice down to code
    - Debug the slice ...

Why do we need new instructions?

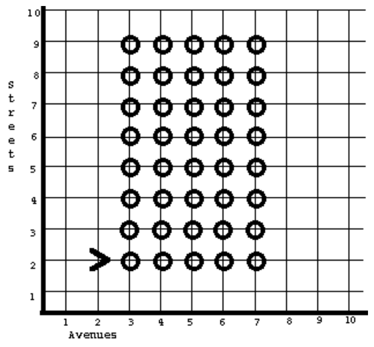
- Make the program readable and understandable
    - Compare with section 3.9.3 of Pattis
    - Chunking and naming!
- Make the programs easy to debug
    - Planning vs. implementation errors
- Make the programs easy to modify to solve variations of the original task
    - Modified Harvest problems

Modification 1: Longer Rows



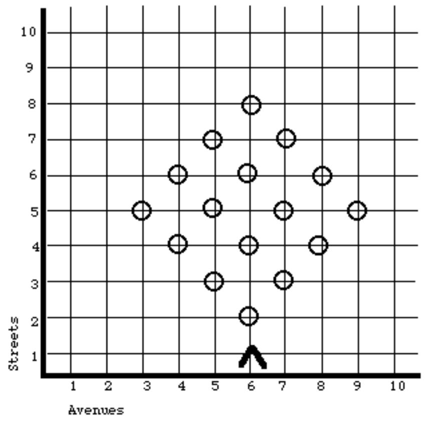
- Where the changes are localized?

Modification 2: More Rows



- Where the changes are localized?

Modification 3: Now what?



- Can we solve this problem by modifying the original harvest program?
- Complete exercise 3.11-5 at home

Before next lecture:

- Reading assignment: Pattis, Chapter 3
- Run Classroom Examples
- Check yourself by doing exercises 1,2, and 9 from Section 3.11. Practice top-down design approach.
- Attempt to solve exercise 5 with minimal changes to the harvesting program
- Homework 2 (due 9/14/04)
  – Solve the specified problem using at least two new instructions. Use top-down design!