IS12 - Introduction to Programming

Lecture 5: Loops

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The `iterate` instruction

- How to repeat an action known number of times?

```
iterate <positive-integer> times
    <instruction>;
```

- Example:

```
iterate 5 times
    move;
```

- Note indentation!

`iterate` instruction with a block

```
iterate <positive-integer> times begin
      <instruction-1>;
      <instruction-2>;
      ...
      <instruction-k>;
end;
<next-instruction>;
```

- Semantics of execution
  - A sequence of instructions from `instruction-1` to `instructionk` will executed `positive-integer` times. After that - `next-instruction`

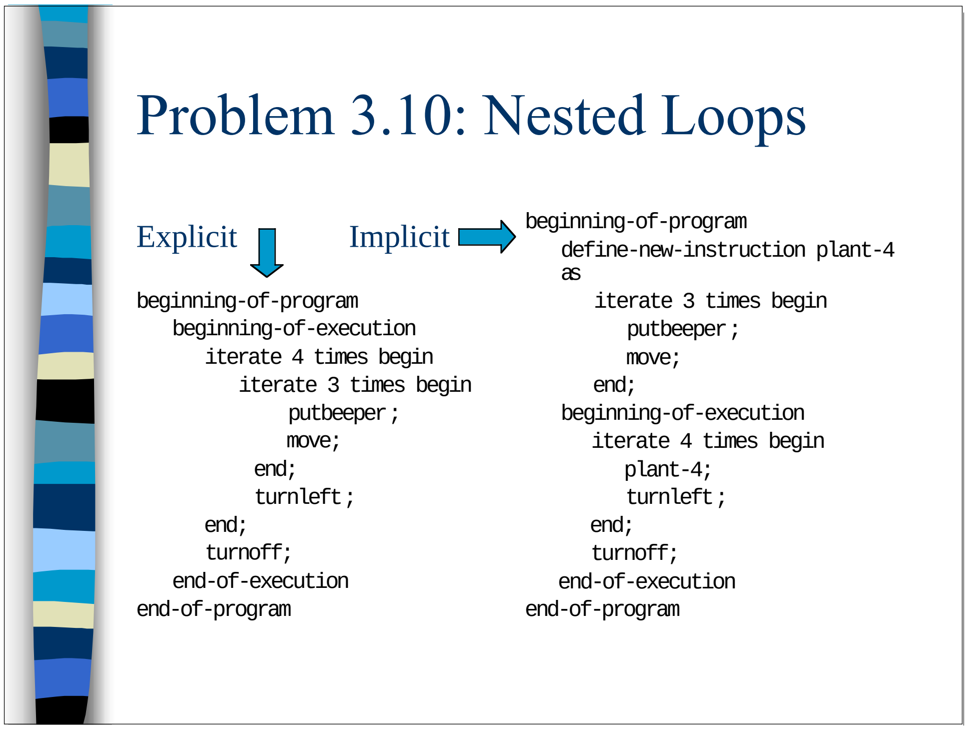
Example 1: Square Dance

New way ⇩

```
beginning-of-program
  beginning-of-execution
      iterate 4 times begin
            move;
            turnleft;
      end;
      turnoff;
  end-of-execution
end-of-program
```

Old way ⇨

```
beginning-of-program
  beginning-of-execution
      move;
      turnleft;
      move;
      turnleft;
      move;
      turnleft;
      move;
      turnleft;
      turnoff;
  end-of-execution
end-of-program
```



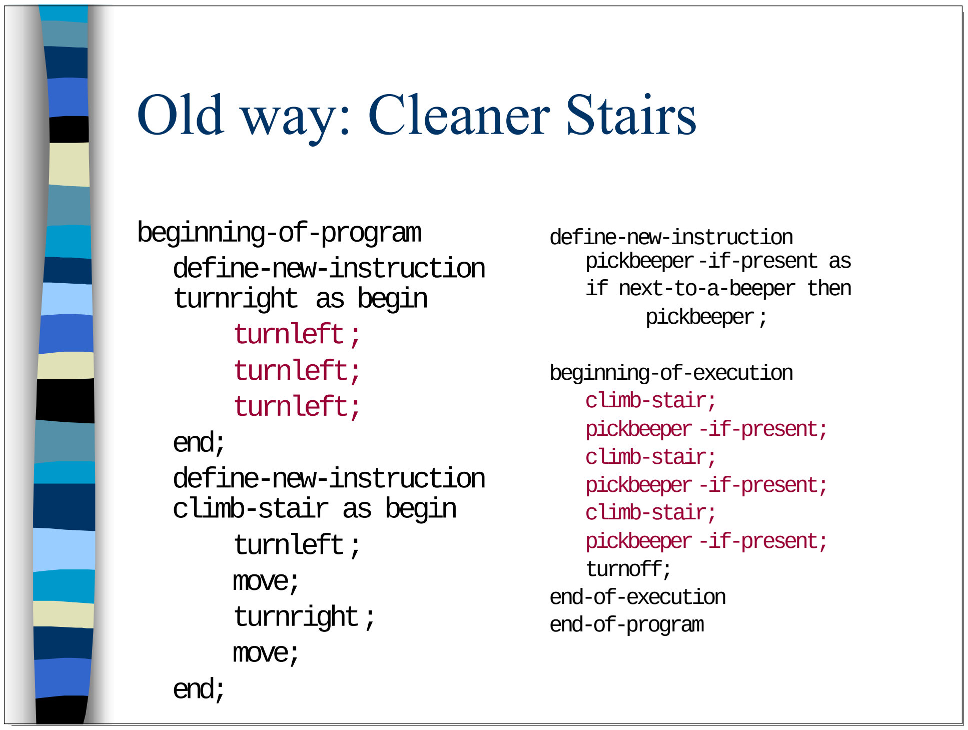
Problem 3.10: Nested Loops

Explicit

```
beginning-of-program
   beginning-of-execution
      iterate 4 times begin
         iterate 3 times begin
             putbeeper;
             move;
         end;
         turnleft;
      end;
      turnoff;
   end-of-execution
end-of-program
```

Implicit

```
beginning-of-program
   define-new-instruction plant-4
   as
      iterate 3 times begin
         putbeeper;
         move;
      end;
   beginning-of-execution
      iterate 4 times begin
         plant-4;
         turnleft;
      end;
      turnoff;
   end-of-execution
end-of-program
```



Old way: Cleaner 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;
```

```
define-new-instruction
   pickbeeper-if-present as
   if next-to-a-beeper then
        pickbeeper;

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

New Way: Cleaner Stairs 2

Is iterate always good?

```
beginning-of-program
   define-new-instruction
   turnright as
      iterate 3 times
          turnleft;

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

```
define-new-instruction
   pickbeeper-if-present as
   if next-to-a-beeper then
        pickbeeper;

beginning-of-execution
   iterate 3 times begin
        climb-stair;
        pickbeeper-if-present;
   end;
   turnoff;
end-of-execution
end-of-program
```

Old way: Carpet (problem 3.8)

```
beginning-of-program
   define-new-instruction
   laycarpet as begin
      move;
      putbeeper;
      move;
      putbeeper;
      move;
      putbeeper;
      move;
      putbeeper;
      move;
      putbeeper;
      move;
      putbeeper;
      move;
      putbeeper;
   end;
```

```
   beginning-of-execution
      laycarpet;
      turnleft;
      laycarpet;
      turnleft;
      laycarpet;
      turnleft;
      laycarpet;
      turnoff;
   end-of-execution
end-of-program
```

New way: Carpet (problem 3.8)

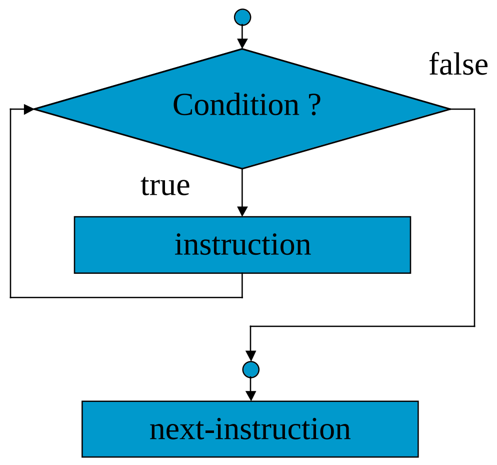
```
beginning-of-program
   define-new-instruction
   laycarpet as
   iterate 7 times begin
        move;
        putbeeper;
     end;
   beginning-of-execution
      iterate 4 times begin
         laycarpet;
         turnleft;
      end;
      turnoff;
   end-of-execution
end-of-program
```

`while` loop

```
while <condition> do
        <instruction>;
<next-instruction>;
```

- Semantics of execution
  - While condition is true - `instruction` is executed over and over.
  - After that - `next-instruction`
  - What if it is wrong right away?

Flowchart of `while`



`while` instruction with a block

```
while <condition> do begin
      <instruction-1>;
      <instruction-2>;
      ...
      <instruction-k>;
end;
<next-instruction>;
```

- Semantics of execution
  - While condition is true - `instruction-1 ... instruction-k` repeated over and over
  - after that - `next-instruction`

Examples

- Find beeper

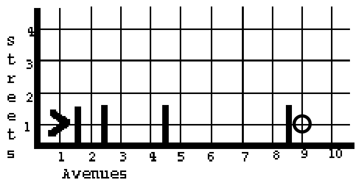
```
define-new-instruction go-to-beeper as
   while not-next-to-a-beeper do
        move;
```

- Get all beepers

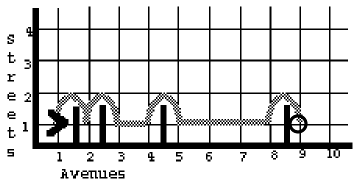
```
define-new-instruction clear-corner-of-beepers as
   while next-to-a-beeper do
        pickbeeper;
```

Case 1: Long Race to a Beeper

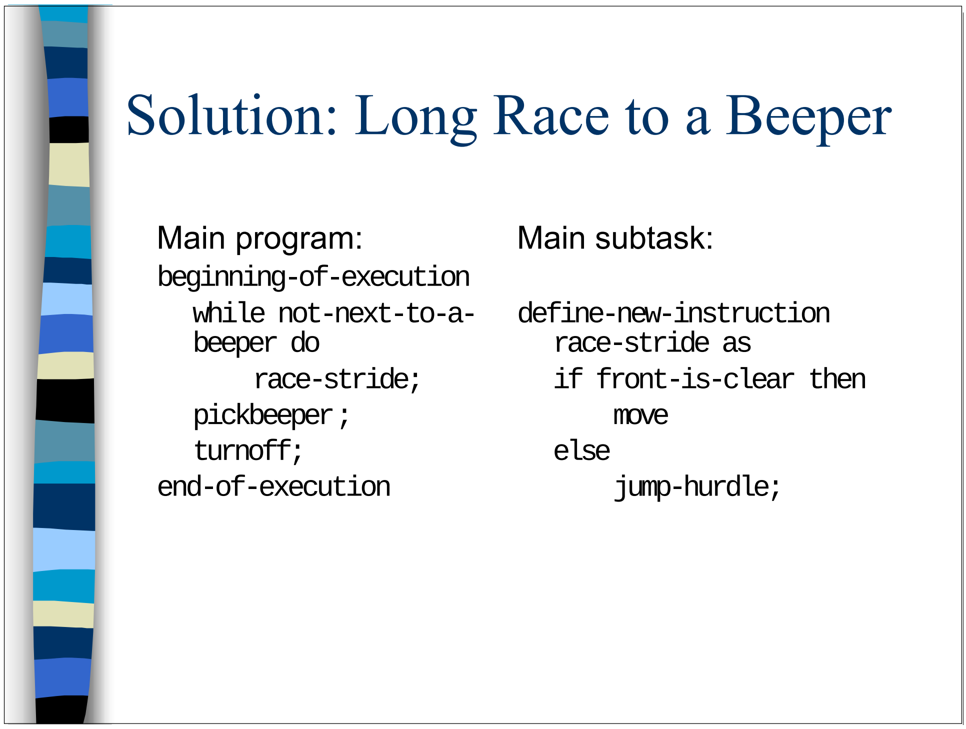
- Move Karel through a row of “hurdles”
- Each pair of Avenues may or may not have a hurdle between them
- The race is arbitrary long
- There is a beeper at the end of the course



Initial Situation



Final Situation



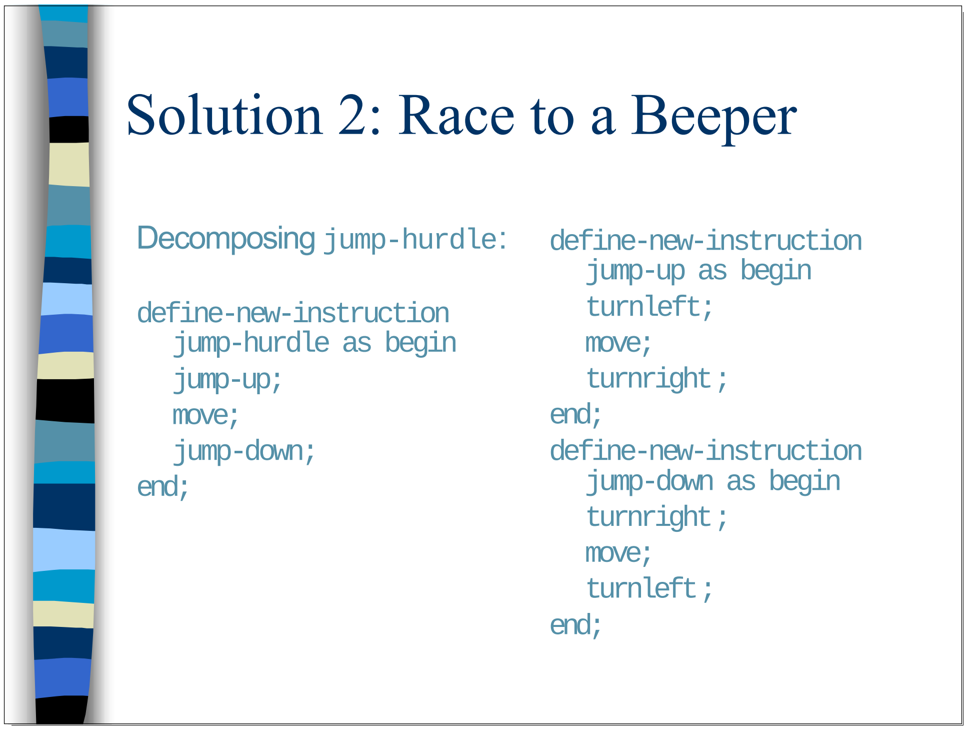
Solution: Long Race to a Beeper

Main program:

```
beginning-of-execution
   while not-next-to-a-
   beeper do
        race-stride;
   pickbeeper;
   turnoff;
end-of-execution
```

Main subtask:

```
define-new-instruction
   race-stride as
   if front-is-clear then
        move
   else
        jump-hurdle;
```



Solution 2: Race to a Beeper

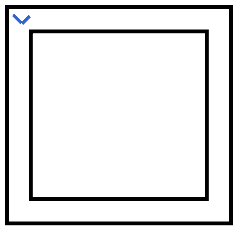
Decomposing `jump-hurdle`:

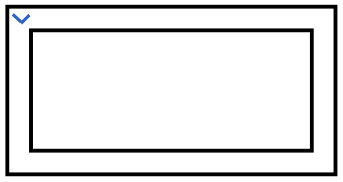
```
define-new-instruction
   jump-hurdle as begin
   jump-up;
   move;
   jump-down;
end;
```

```
define-new-instruction
   jump-up as begin
   turnleft;
   move;
   turnright;
end;
define-new-instruction
   jump-down as begin
   turnright;
   move;
   turnleft;
end;
```

Case 2: Lay Any Carpet

```
beginning-of-program
   define-new-instruction
   lay-carpet-side as
     while front-is-clear do begin
        move;
        putbeeper;
     end;
   beginning-of-execution
      iterate 4 times begin
         lay-carpet-side;
         turnleft;
      end;
      turnoff;
   end-of-execution
end-of-program
```





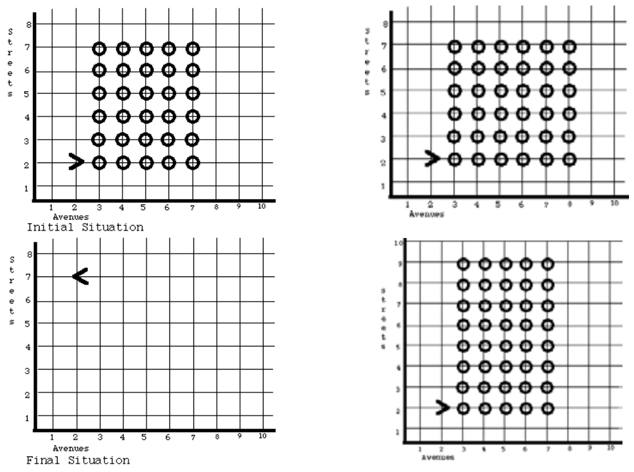
Steps of Building a While loop

- What should be true when Karel has to finish the loop?
- Use opposite condition for while test
- “Frame” the while - do what you need before/after to solve the problem
- Do the minimum what is needed to ensure that the loop eventually stops

Loop Invariant and Changes

- At the beginning of every iteration:
  - What is always the same - some condition that is true when we need to execute the loop body and false when we do not need to do it anymore?
  - What is different for each subsequent iteration that makes the new situation closer to the solution than previous?

Universal Harvest Program



Original Solution for Harvest

```
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
```

While Loops in Harvest

```
beginning-of-execution
   move;
   // at the beginning of every
   // iteration  Karel stands at
   // the beginning of the next
   //  double row facing east
   while next-to-a-beeper do
   begin
        harvest-1-row;
        go-to-next-row;
        harvest-1-row;
        position-for-next;
   end;
   position-for-next;
   move;
   turnoff;
end-of-execution
```

- What is true at the beginning of every iteration?
  - at the beginning of every iteration Karel stands at

    the beginning of the next

    double row facing east
- What is different for each subsequent iteration that makes it closer to the solution?
- How we had to "frame" this loop?

While Loops in Harvest

```
define-new-instruction harvest-
   1-row as begin
        while next-to-a-beeper
        do begin
            pickbeeper;
            move;
        end;
        step-back;
end;
define-new-instruction step-
   back as begin
        turnleft;
        turnleft;
        move;
        turnleft;
        turnleft;
end;
```

- What is true at the beginning of every iteration?
- What is different for each subsequent iteration that makes it closer to the solution?
- How we had to "frame" this loop?

Before next lecture:

- Do reading assignment
  - Pattis: Chapter 5
  - Tutorial: lessons 8, 11
- Run Classroom Examples
- Check yourself by doing any 3 from exercises 4-13 from Section 5.9
- HW3 is due on 9/23/04