Algorithmic Thinking and Structured Programming (in Greenfoot)

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Today’s Lesson plan (13)

Warming-up:

- Present your Dodo’s race algorithm to the class
- Reflection: Have you been using Computational Thinking?

Core:

- Recursion and BlueJ

Wrapping-up:

- What to expect on final test
- Course survey

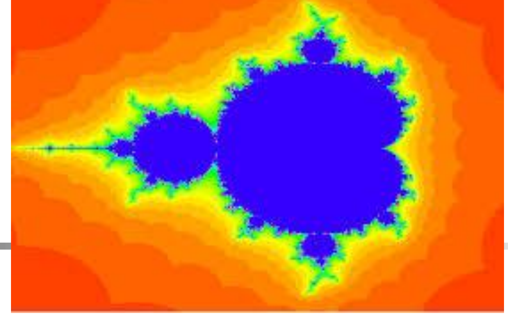
Computational thinking

- **Working in a structured manner:**
  - Break problems down into subproblems
  - Design, solve and test solutions to subproblems
  - Combine (sub)solutions to solve the problem
- **Analyzing** the quality of a solution
- **Reflecting** on the solution chosen and proces
- **Generalizing** and reuse of existing solutions

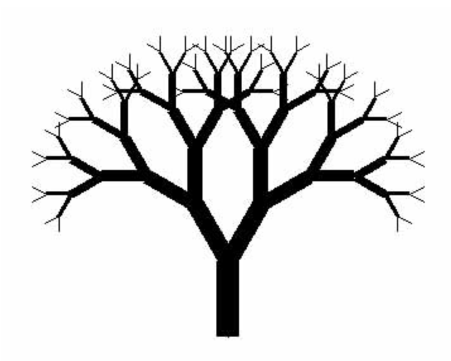
BlueJ

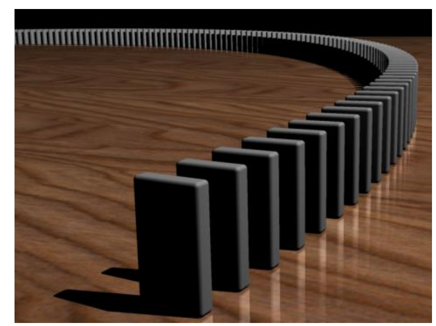
Different programming environment (as opposed to Greenfoot)
Same language: Java

Recursion



- A smaller part of oneself is embedded in itself
- Many natural phenomena are recursive





(a) Trees (b) Infinite mirror images (c) dominos

Sometimes, it is easier to solve a given problem using recursion

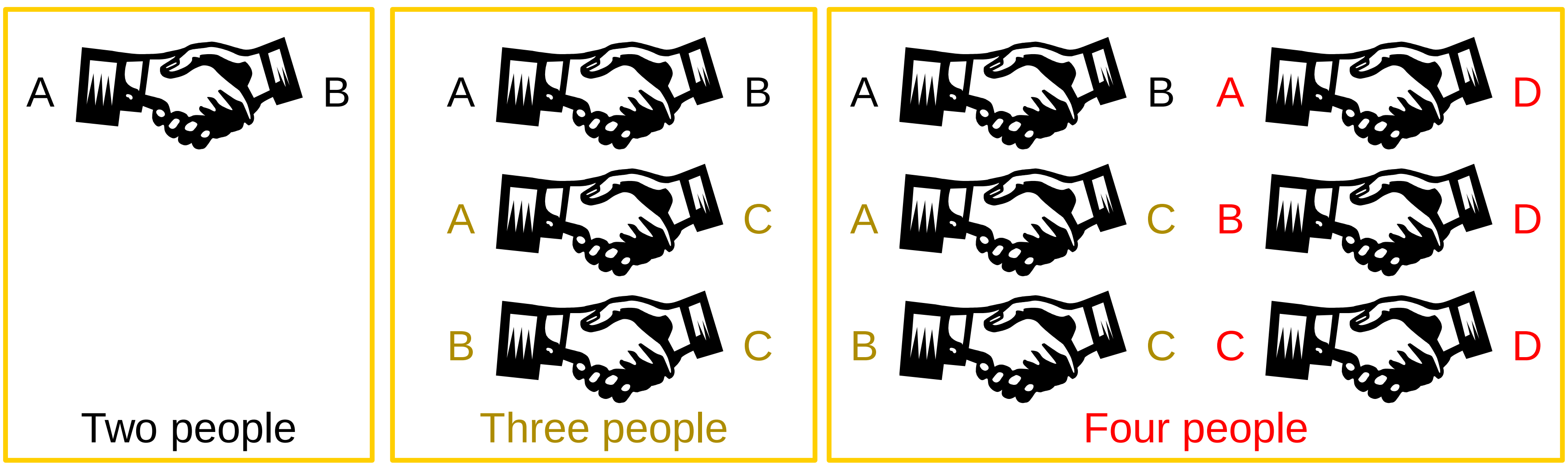
Recursive Definitions

- In a recursive definition, an object is defined in terms of itself (but then smaller).
- We can recursively define sequences, functions, sets, ...
- Recursion is a principle closely related to mathematical induction.

Ex. 1: The handshake problem

Question: There are *n* people in the room.

If each person shakes hands once with every other person, what will the total number of handshakes be?



Ex. 1: The handshake problem (cont’d)

- There is a trick to know the total number
  - If there are **two** people, only one handshake

h(2) = 1

let **h(n)** calculate the number of handshakes needed,
n ‘*the number of people*’ is 2,
h(2) **‘***the number of handshakes for 2 people*’ equals 1.

so **h(2) = 1**

Ex. 1: The handshake problem (cont'd)

- There is a trick to know the total number
  - If there are **two** people, only one handshake
  - If there are **three** people, treat it as having one more person added to the two people, and shakes hands with them (2 extra handshakes)

h(2) = 1

h(3) = h(2) + 2

let **h(n)** calculate the number of handshakes needed,
n '*the number of people*' is 3,
h(3) '*the number of handshakes*' for 3 people equals:

- the number of handshakes needed for 2 people, so **h(2)**
- plus two more handshakes, so + 2

so **h(3) = h(2) + 2**

Ex. 1: The handshake problem (cont'd)

- There is a trick to know the total number
  - If there are **two** people, only one handshake
  - If there are **three** people, treat it as having one more person added to the two people, and shakes hands with them (2 extra handshakes)
  - If there are **four** people, treat it as having one more person added to the three people, and shakes hands with them (3 extra handshakes)

h(2) = 1

h(3) = h(2) + 2

h(4) = h(3) + 3

let **h(n)** calculate the number of handshakes needed,
n '*the number of people*' is 4,
h(4) '*the number of handshakes*' for 4 people equals:

- the number of handshakes needed for 3 people, so **h(3)**
- plus two more handshakes, so + 3

so **h(4) = h(3) + 3**

Ex. 1: The handshake problem (cont'd)

- There is a trick to know the total number
  - If there are two people, only one handshake — **h(2) = 1**
  - If there are three people, treat it as having one more person added to the two people, and shakes hands with them (2 extra handshakes) — **h(3) = h(2) + 2**
  - If there are four people, treat it as having one more person added to the three people, and shakes hands with them (3 extra handshakes) — **h(4) = h(3) + 3**

- We can **generalize** the total number of handshakes into a formula:

$$\begin{array}{ll} h(n) = h(n-1) + (n-1) & \text{if } n >= 2 \\ h(n) = 0 & \text{otherwise} \end{array}$$

Ex. 2: Factorial function

- Recursion is useful for problems that can be represented by a simpler version of the same problem
- Example: the factorial function

$$6! = 6 * \underbrace{5 * 4 * 3 * 2 * 1}_{\mathbf{5!}}$$

We could write:

$$6! = 6 * 5!$$

Ex. 2: Factorial function

In general, we can express the factorial function as follows:

n! = n * (n-1)!

Is this correct? Well… almost …

The factorial function is only defined for *positive* integers. So we should be a bit more precise:

n! = n * (n-1)!	(if n is larger than 1)
n! = 1	(if n is equal to 1)

Recursion

- Recursion is one way to **decompose** a task into smaller subtasks
  - Each of these subtasks is a simpler example of the same task
  - The smallest example of the same task has a non-recursive solution

- The factorial function
  - n! = n * (n-1)! (simpler subtask is (n-1)!)
  - 1! = 1 (the simplest example is n equals 1)

How many pairs of rabbits can be produced from a single pair in a year's time?

- Assumptions:
  - Each new pair of rabbits becomes fertile at the age of one month
  - Each pair of fertile rabbits produces a new pair of offspring every month;
  - None of the rabbits dies in that year.

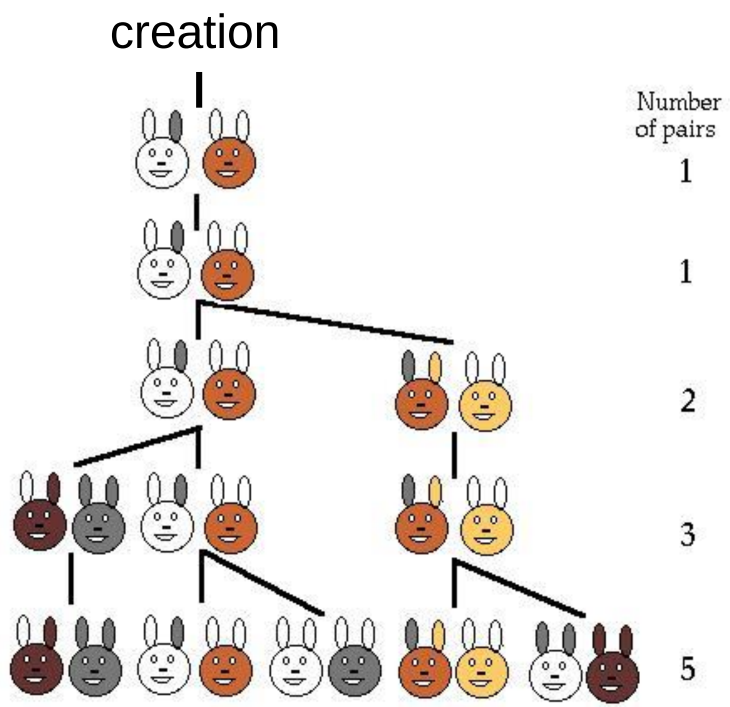
- How the population develops:
  - We start with a single pair of (newborn) rabbits;
  - After 1 month, the pair of rabbits become fertile
  - After 2 months, there will be 2 pairs of rabbits
  - After 3 months, there will be 3 pairs (2+1=3)
  - After 4 months, there will be 5 pairs (since the following month the original pair and the pair born during the first month will both produce a new pair and there will be 5 in all (2+3=5).

Monthly rabbit population: 1, 1, 2, 3, 5, …

Population growth in nature

- Leonardo Pisano (nickname: Fibonacci) proposed the sequence in 1202 in *The Book of the Abacus.*

Monthly rabbit population: 1, 1, 2, 3, 5, …



How many pairs of rabbits can be produced from a single pair in a year's time?

- Can you **generalize** the total number of pairs into a formula?

- Monthly rabbit population: 1, 1, 2, 3, 5, …

- Reminder. Our handshake formula:

h(n) = h(n-1) + (n-1)   if n >= 2
h(n) = 0   otherwise

Fibonacci

- Fibonacci numbers:

  0, 1, 1, 2, 3, 5, 8, 13, 21, 34, ...

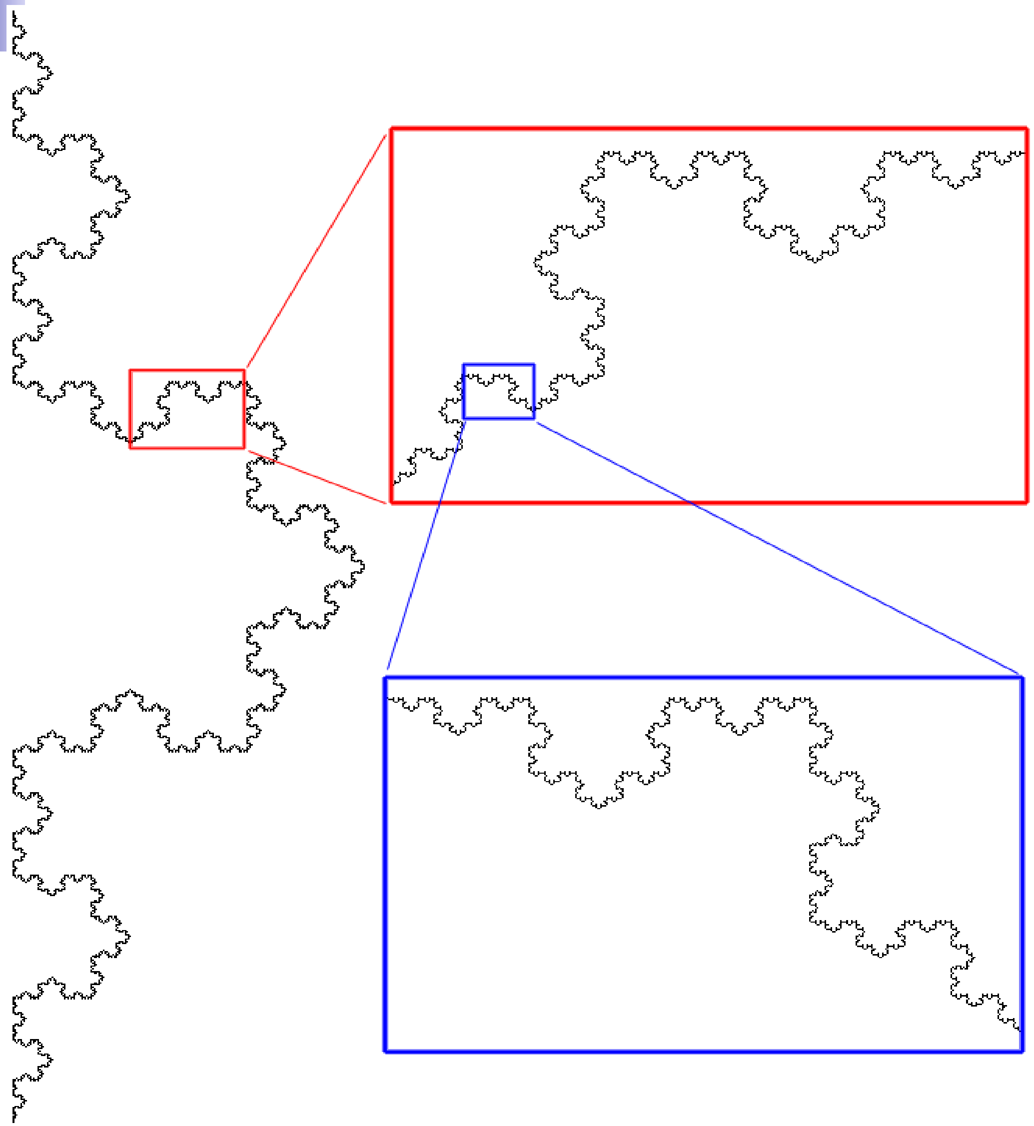
  where each number is the sum of the preceding two

  example: f(2) = f(1) + f(0)

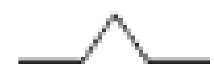
  f(3) = f(2) + f(1)

- Recursive definition:
  - **F(0) = 0** **(Fibonacci number at 0th position)**
  - **F(1) = 1** **(Fibonacci number at 1st position)**
  - **F(number) = F(number-1)+ F(number-2)**

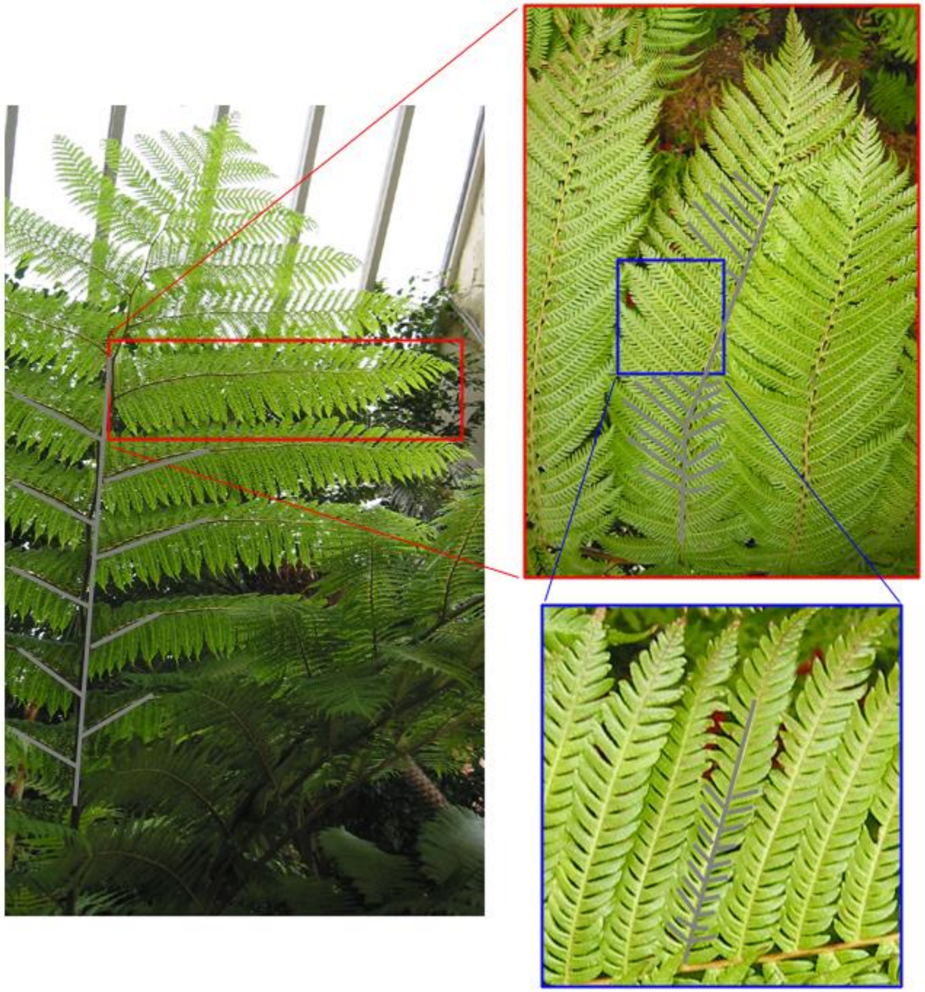
Fractals: self-similar patterns



Self-Similarity in Fractals

- Exact
- Example Koch snowflake curve
- Starts with a single line segment
- On each iteration replace each segment by 
- As one successively zooms in the resulting shape is exactly the same

Self-similarity in Nature



BlueJ and recursion

- BlueJ is environment (IDE) for Java programming (as an alternative for Greenfoot).
- In this assignment you will experiment with recursion.

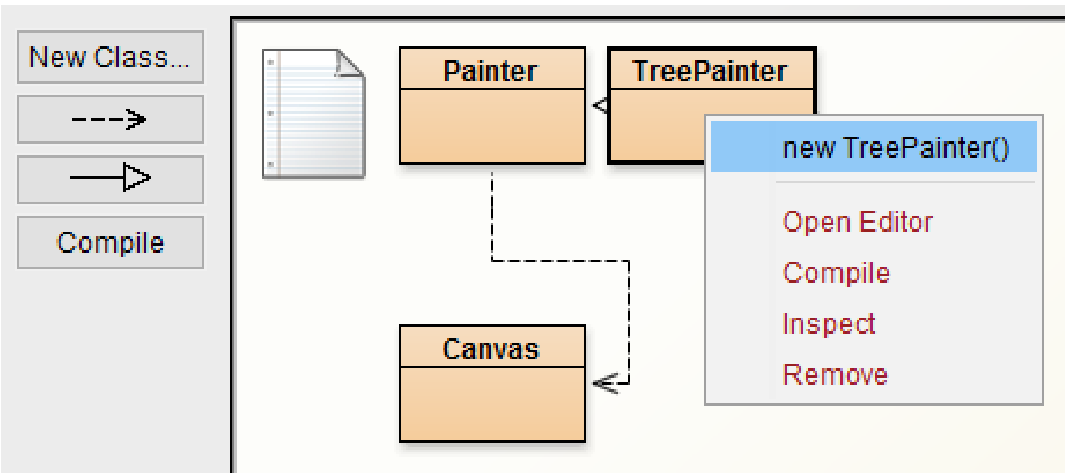
Drawing trees:

- Using recursion typically less effort than ‘by hand’
- Recursive definition is the basis for animated movies and games.


Getting started with BlueJ

How to call a tree-drawing method

1. Right-click on the TreePainter class and select ‘new TreePainter()’



2. An empty canvas is created. Move it aside (don’t click it away).
3. In the bottom of the screen, right-click on the instance you just created: 

4. Choose one of the methods to draw a tree.
5. Each time you wish to draw a new tree, repeat the steps above. You can keep multiple canvases open at a time.

Canvas orientation

- Coordinates are as you are accustomed to in math (opposed to Greenfoot)
- Origin (0,0) is in the bottom left corner
- Always starts facing East
  - After turning 90 degrees (counterclockwise), pointer faces North

Understanding drawSimpleTree

void **drawSimpleTree**(double length, double beginX , double beginY, double dir)

Tinker (“play around with”) assignment:

- Run, view and analyze the code
- Try to figure out how it works.

Calculating coordinates and angles

Method is given `beginX`, `beginY`, `length` and `dir`

Must calculate endX and endY and new direction

Calculate x coordinate for end of branch:

- `double endX = beginX + length * Math.cos ( dir );`

Calculate y coordinate for end of branch:

- `double endY = beginY + length * Math.sin ( dir );`

Calculate next angle:

- dir + `bendAngleSimpleTree`
- `double bendAngleSimpleTree = 22.0/180 * Math.PI;`
  `(uses 22 degrees and then turns degrees into radians)`

drawSimpleTree method explained

The first time method is called with the **trunk** information:

```
public void drawSimpleTree() {
      drawSimpleTree( 180, CANVAS_WIDTH/2, 50, Math.PI/2 );
   }
```

After drawing the **trunk**, the method calls itself **2** times, each time with a **shorter branch** and a **new direction**:

```
void drawSimpleTree( double length, double beginX , double beginY, double dir )
      ….
      drawLine( beginX, beginY, endX, endY);
      double lengthSubTree = length * shrinkFactorSimpleTree; // shrink branch
      drawSimpleTree ( lengthSubTree, endX , endY, dir + bendAngleSimpleTree );
      drawSimpleTree ( lengthSubTree, endX , endY, dir - bendAngleSimpleTree );
}
```

The algorithm **stops** when the branches become too small

(**shorter than length 2**)

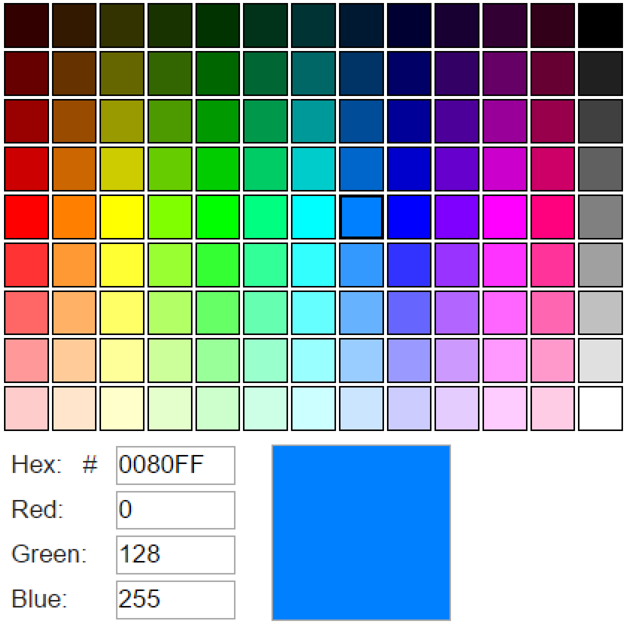
drawSimpleTree code tracing

drawPurpleTree method explained

More variation:

- Use of colors
- Define colors using RGB (Red-Green-Blue) color space

```
setPenColor ( 0, 128, 255 );
```



Tinker assignment:

- Experiment with a different (more **natural**) pen color
- Tip: Google “RGB table”

drawFullBodyTree method explained

More variation for an even more natural look:

- Branch **thick**ness

- Algorithm:
  - If branch length is long (tree trunk and main branches)
    - Branch is drawn **thick**
  - else, the length is short (small branches & leaves)
    - Branch is drawn thin (with minimum of 1 pixel)

Tinker assignment:

- Run, view and analyze the code.
- Experiment with a different `length` and `treeLengthWitdthRatio`

drawMinorRandomTree explained

More variation for an even more natural look:

- Randomness
  - `getRandomNumber( 60, 90 )`

  returns a random int between 60 and 90

- Algorithm:
  - Branch length is shrinked by a shrinkFactor
    - between 60% and 90%
    - subtree is drawn

drawNaturalTree

Assignment: Write your own tree method

- Add more variation for a more **natural** look:
  - Combining branch **thick**ness and use of colors
  - More randomness of angles and lengths
  - Incorporate randomness in colors
    - Use appropriate colors, i.e. different (random) shades of green/brown, but not hot-pink
- Randomness in branches:
  - Occasionally leave out a branch
  - Occasionally draw one branch in front of the other

- .. What else can you draw? (a Christmas tree???)

- Write a new method
  - Copy the code from `drawSimpleTree`
  - Add code, inspired from:
    - `drawPurpleTree`
    - `drawFullBodyTree`
    - `drawMinorRandomTree`

Questions?

Wrapping up

- Final test: what to expect (next sheet)
- Final assignment: send us your MyDodo.java file
- Final course survey: http://goo.gl/forms/VH8uQbEkRS

Test: what to expect

- During testweek
- Theory in assignments 1 through 7
- Similar to the quizzes
- A bit of theory
- Algorithms, flowcharts and code:
  - Designing
  - Analyzing
  - Writing

Thank You!!

And as a final remark:

Thank you all!

We really enjoyed teaching you ☺

After handing in MyDodo.java and passing the final test:

- **Hand in USB stick**
- **You will get a certificate from the RU**
- **Be sure to include this on your CV!!**