Teaching Computational Thinking with L-Systems and Turtle Graphics

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L-Systems
Lindenmayer-systems, or L-systems are a formal grammar created by Lindenmayer and Prusenkeiwcz to model the development of biological systems. L-systems are the basis for many plant and tree models in computer graphics. L-systems can produce strings that have a natural turtle graphics interpretation. L-systems differ from regular grammars in that a substitution rule applies to all instances of a symbol simultaneously. This models cells dividing in parallel within an organism.

Example:
Alphabet: F, +, -
Base string: F
Rules: F -> F-F++F-F

Project 1
Introduces students to 1-rule L-systems with a small alphabet: forward (F), left (+), right (-), push ([), and pop (]).

Students read the L-system parameters and rule from a file and write the code to implement substitution.

Students write a separate transformer module to interpret a string and execute turtle actions, including pushing and popping the turtle state from a stack.

Students have to create a simple scene containing several different types of L-systems.

Project 2
Students re-implement the L-system representation using a class instead of a list of lists.

The new class implements multi-rule L-systems, which requires a new substitution algorithm and the ability to copy information from nested lists.

The transformer module becomes a class and abstracts the turtle commands so students can create scenes by orienting and placing objects created from L-systems, which now have a larger alphabet.

Project 3
Students use dictionaries to implement stochastic L-systems. Stochastic L-systems permit a replacement rule to choose randomly from multiple possible strings. They have to write a new substitution algorithm that integrates random choice.

Students implement a Shape parent class that stores the information required to interpret a string as turtle commands and knows how to draw itself using the Transformer class.

Students create several child classes that override the constructor to use a different string.

Project 4
Introduces students to non-photorealistic rendering (NPR), using abstraction to override the turtle’s forward command.

The Transformer class can draw an object according to a style. The style parameter controls the action of the forward command.

Students implement at least three different styles.

Project 5
Students expand their L-system, Transformer, and Shape classes to make use of a 3D turtle package developed by the author on top of Tkinter.

Because of the prior design, students are able to easily generate 3D shapes and draw them in different NPR styles.

The underlying structure is identical. The shape classes define a 3D shape using a string. The Transformer class interprets the string into graphics commands. The forward command implements the NPR settings, and the 3D turtle does the drawing.

All assignments and lab exercises are available at [http://cs.colby.edu/maxwell/courses/cs151/S09](http://cs.colby.edu/maxwell/courses/cs151/S09) as projects 8 through 12.