Visual Examples of Recursion

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ABSTRACT

Because recursion is generally introduced early in the curriculum, the range of problems that can be used to motivate its study is limited. We describe three interesting visual problems that use recursion effectively. Each problem demonstrates the utility of recursion in an engaging way while being appropriate for students nearing the end of CS1.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer and Information Science Education—*Computer Science Education*

General Terms

Algorithms, Design

Keywords

Recursion, Recursive Algorithms, Pedagogy, Computer Science Education, Graphical Projects, Student Engagement

1. MOTIVATION

Solving problems recursively requires students to expand the way that they look at problems, and to consider them from another perspective. In our experience, many CS1 students resist this change, in part, because they see few practical reasons for using recursion. We believe that this is partly a reflection of the traditional examples that we have used to teach recursion in the past. As such, we have revised our course materials to include examples designed to meet three goals:

- **Utility of Recursion:** The problem being solved must be at least as easy to solve using recursion as it is to solve using imperative control structures.
- **Relevance:** The problem under consideration should serve some practical purpose.
- **Engaging:** The problem being solved should be interesting to the students who are being taught.

The remainder of this document describes three interesting visual problems which meet each of the constraints outlined above. We have successfully used the first two problems to improve our students' understanding of recursion, and we anticipate using the third problem during the current academic term.

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2. FRACTALS

The last time we taught recursion in CS1, we introduced the students to fractals. This introduction included examining simple fractals such as the Sierpinski triangle and fractal fern during lecture, as well as an assignment that asked students to create a program that draws the fractal t-square. My colleagues have also had success with an assignment that asked students to draw the Hilbert Curve. Our impression was that most students were genuinely interested in this application of recursion because it allowed them to generate visually interesting patterns. We also outlined how fractal images can be used for practical problems such as automatic terrain generation. As a result, we were left with the strong impression that we had engaged our students by solving a relevant problem that is well suited to recursion.

3. FLOOD FILL

We have also used the flood fill or "paint bucket" algorithm to motivate the study of recursion. This operation, which changes the color of an arbitrarily shaped region within an image, is available in many image manipulation programs. As such, it is familiar and relevant to most students.

Students had greater difficulty implementing the floodfill algorithm than drawing the fractal t-square. We attribute this to the need to modify a data structure rather than to generate output directly. As a result, they did not receive the same kind of immediate feedback that was available to them when drawing the fractal. While the problem was more difficult, we still felt that it was appropriate for use near the end of CS1, and that it was successful at meeting our goals.

4. MAZE

Recursion is also well suited to finding a path through a maze. While we have not yet used this example with our students, we expect that they will find it engaging and relevant due to its visual nature and applications to computer games. While path finding can also be performed using an iterative algorithm, the iterative solution requires the use of a stack or a queue. We do not introduce these data structures in CS1, and as such, we are also confident that students will view this as a useful example of recursion.

5. SUMMARY

We have presented three graphical problems with natural recursive solutions. Each meets our goals of demonstrating the utility of recursion while also being relevant and engaging for students.