Finding the Light: On the Distribution of Leaves

Katie Lewis

April 30, 2004
Introduction

Life, in all its vibrance, variance, and complexity fills our planet from wide open plane to rock crevice. A person may spend their entire life studying even a minor subpart of this enormous dance. The concepts being studied in biology are still very high level; the bridge between physical description of reality and the description of life which sits on that foundation still has a way to go. As we are reaching further in understanding our own makeup the potential for biological applications in industry is viewed as one of the most promising fields for the next wave of innovation. Such expected innovation need not be considered as restricted to medicine.

At a high level, humanity has long looked out at reality and asked "Why?". One such broad sweeping 'why' question that may be asked is "Why do plants look the way they do?" To study such a phenomenon properly, one should attempt to study the chemistry that makes up the plant and the higher level mechanism these processes lead to. One speculates what things may and may not be advantageous to a plants survival and what aspects may simply be a matter of chance. One wonders, 'what were the chances evolutionarily that this plant should turn out this way?' 'What impact do different factors have on the resulting structure of plants over time?'

To address these sorts of questions in any proper way requires a lot of empirically determined data. In order to study life that exists one must have data on life that exists. However, one may abstract the problem to a higher level, one may consider broader questions. One may ask 'if life were like this then how would this turn out?' Such interrogations will not answer a question of a real plants structure as such. Well, one could conjecture that one's model was the same as plants if it seemed to match, and empirical data might support this, but even if one produced such similar results, one wouldn't really have a proper establishment of the plants properties until the underlying mechanisms are understood. In abstracting the problem, however, one gains something else. One can isolate aspects of the issues in a way impossible to do with real life forms. For example, in a mental model, one might say, 'assume spherical leaves.' This is hardly a practical thing to achieve in real life. But, if leaves aren’t spherical, why should we care what happens if you have them? In learning physics, one will often assume things like 'suppose no gravity' or 'suppose a frictionless plane' because it allows one to isolate just the parts of the problem one is interested in. In early mathematics when one wished to solve a series of equations with unknowns one combines and substitutes the equations until a single unknown is isolated and becomes known. If one wishes to understand the rules of a system, it is best to isolate them.

The Question: Qualitatively

In a simplified concept of a plant (as below defined), what is the effect of sunlight distribution, leaf shape, leaf size, and other parameters on the structure of the plant and the distribution of its leaves?

The Question: Quantitative

Can mathematical functions be found to describe the qualitative considerations above stated?

1st Set of Assumptions

- For modeling purposes, I am considering a plant to consist of straight line structures with discrete points at which the structures 'branch'.

- I am assuming a plant leaves the ground at a single place.

Having cast the form of a plant into this description, I make the simplifying assumption that the likelihood of a plants survival may be calculated based on some function of the plants structure (number of branches, length of branches, number of leaves, placement of leaves, etc) and some function of the leaf surface area’s contact with light.
2nd Set of Assumptions

Having defined this fundamental conception of a plant, I simplify the problem still further with a variety of second assumptions.

These second assumptions are parameters I may change from trial to trial in order to see what affect they have on the resulting plant structure and leaf distribution. Given time constraints, most of these parameters will not be tested in this study, but they are listed here to be kept in mind in expanding this study.

These parameter assumptions are:

Light Distribution
- Directly down
- At an angle
- Filtered through randomly generated canopy
- "Ambient" (i.e. uniform in all directions from outside of the plant)
- Joint modeling: modeling plants next to each other and having them fight for light

Leaf Shape
- Flat rectangle
- Sphere
- Cube
- "Fingers"
- Actual leaf shapes

Other parameters
- Leaf size
- Amount of light a leaf will see through another leaf
- Restrictions on number of branches coming out of a single branch point

And Most Importantly
The function for calculating the benefit of leaf-sunlight surface and the function for calculating the cost of plant structure

Parameters that may or will vary
- Leaf location
- Leaf orientation
- Leaf size

Also
The structure of the approach of studying these different parameters.
Method of Approach

In order to see what sort of plant patterns are favored for given parameters, I coded a plant class in C++, consisting of location nodes connected by pointers, and an evolutionary program, which cycles through a number of iterations generating, mutating, crossing, and culling plants.

Sort of results expected

In running this program we can know exactly what parameters are fed into it, and at any point in the simulation we can calculate information such as:

- The number of branching points in the plant.
- The number of leaves in the plant.
- The location of all the leaves, all the branch points and all the branches.
- The total length of branches.
- The total length of branches separated by number of nodes from the root.
- The height of the plant.
- All of the parameters such as leaf shape and size which were fed in.
- The orientation of the leaves.
- In many cases: The amount of leaf overlap.

Analysis of the Results

The date should be analyzed in two ways: First qualitatively looking at the results and seeing general trends; second by plotting different parameters against each other such as 'leaf length' versus 'leaf overlap'.

The program as yet is not running and results are waiting upon this.

Where we go from here

Ideally the above model should be used with empirically derived data to see if parameters might be derived that would allow one to model plants that are structurally similar to real ones.

Unclosed

Although this project is at the moment frustrating in its not quite completeness, the conceptualization of a technique for approaching the issue and the basis of the model are not without their merit of consideration. The first hurdle in addressing a curiosity is in articulating it. Furthermore, one must consider if this was a reasonable approach or whether other techniques would have been more practical.

Footnote

Although this model was derived for studying plants, it might be applied in other ways. The most obvious one would be to simulate plants for computer graphics. In this domain all that is required is that plants "appear" realistic. Questions of appeal are an entirely different problem from questions of accuracy.
Appendix: The Code

Email-ed as an attachment and viewable at http://www.cs.hmc.edu/~klewis/SciComp/.