

Towards a Computational Approach for Estimating Ecosystem Productivity: Opportunities for High School Curricula

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Introduction

High School students' conception of modeling rarely extends beyond simple scatter plots and an occasional linear regression. However, current investigations into carbon fluxes and ecosystem productivity afford opportunities for rigorous discussions and activities which clearly differentiate mechanistic, statistical, and alternative modeling techniques.

A computational model that estimates productivity of the creosote bush can serve as a vehicle for hands-on learning in areas from allometry (relationship between size and shape) to algorithmic recursion.



Objectives & Key Content Areas

The ostensible objective of the model is calculating productivity of different plants, and scaling these calculations up to the ecosystem level. However, within this framework, varied content areas are exposed to investigation, including:

Biology

- Allometry and scaling of metabolic processes
- Carbon flux and ecosystem productivity

Mathematics

- Modeling techniques, validity, and trade-offs
- Rational exponents and logarithmic equations
- Analytic geometry

Fractals

Computer Science / CTE

- Data structures and traversal algorithms
- Recursion
- 3D Imaging and image interpretation

Visual Arts

- Allometric and volume/surface relationships
- Geometric representation of organic objects
- Structure/strength relationships in sculptural objects

Areas of Emphasis

This framework attempts to emphasize *computational thinking*, *active collaboration between secondary and iPlant researchers*, and a *true interdisciplinary approach* at the secondary level. Please refer to the model to the right. The upper panels show the process flow; the lower zone shows opportunities for collaboration and curricular integration of key concepts.

$$Y = Y_0 M^{\frac{3}{4}}$$

A fundamental allometric equation governing scaling of metabolic processes.



Creosote area, adjacent to Empire High School with measurements compliments of Google Earth.



"Omni Oculi", winner of the 2008 Buckminster Fuller sculpture challenge, emphasizes surface-volume relationships.

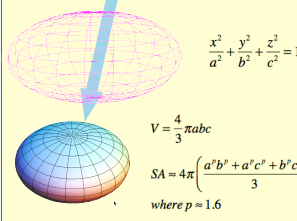
"Render Nature by Means of the Cylinder, the Sphere, the Cone, all Placed in Perspective." -- Paul Cezanne

[1] Geometric Abstraction

The target plant is interpreted as a 3D mathematical object composed of self-similar structures that can be traversed algorithmically. In effect, the plant becomes an object or data structure with properties and inheritance.

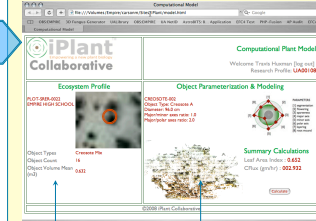


Creosote bush (*Larrea tridentata*) tends to occupy ellipsoidal space, with predictable ratios between equatorial and polar radii.



[2] Modeling and Quantification

Experimental productivity measurements of target plant components supply a baseline profile. This profile is adjusted by seasonal, environmental and physical attributes of a specific instance of the target plant, in iterative cycles of 3D visualization. The outcome of this step is a digital model that approaches structural congruency with the target plant instance.

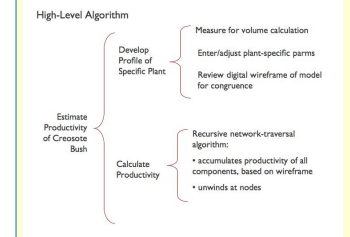


Ecosystem view allows multiple objects in a given area to be summarized

Object view allows individual instances from the ecosystem to be modeled. (Note the non-tabular parameterization UI)

[3] Computation and Scaling

Finally, a computational traversal of the plant instance begins. The self-similar fractal nature of the plant objects can be leveraged with recursive algorithms. Auxiliary computations based on allometric scaling can be employed, extending the models. Steps [2] and [3] can be repeated for all objects in a given ecosystem, possibly with the aid of image-processing techniques which measure all objects in a given satellite image. Students can contrast computational results with statistical and empirical data, and conjecture as to the root causes of discrepancies.



[Biology]
Dr. Huxman guest lecture on carbon flux research. Field trips to towers.

[Visual Art]
Investigate the relationships between volume, surface area, and structural strength.

[Mathematics]
Manipulate equations of geometric solids to model organic objects

[Biology]
Measure carbon flux of individual plant components, plants and ecosystems

[CTE/CS]
Dr. Barnard guest lecture. 3D modeling workshops. Field trips to CAVE.

[CTE/CS]
UI design and development. 3D modeling, image processing.

[Mathematics]
Allometric scaling models, logarithmic equations and rational exponents.

[CTE/CS]
Recursive algorithms; data structures

[Mathematics]
Compare computational models to regression models; discrete to functions

[Biology]
Investigate root causes of carbon flux discrepancies when comparing empirical v. model