A Plan 9 Approach to Hierarchical Patch Dynamics

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Many Problems are Inherently Multiscale

<table>
<thead>
<tr>
<th>Scale</th>
<th>Major Characteristics</th>
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| Regional Landscape | • Composed of different types of local landscapes  
                    • Heterogeneous in ecosystem structure and function  
                    • Characterized by the dominant biome and land use pattern at the regional scale (e.g., an urbanized desert region vs. an agricultural grassland region) |
| Local Landscape    | • Composed of different land use and land cover types  
                    • Heterogeneous in ecosystem structure and function  
                    • Characterized by dominant land use types, such as urban landscapes, rural landscapes, agricultural landscapes, and natural desert landscapes |
| Local Ecosystem    | • Relatively homogeneous vegetation-soil complexes  
                    • Readily detectable from air photos and remote sensing data (e.g., Landsat TM images)  
                    • Largely corresponding to Anderson et al.'s (1976) Level II classes |
Hierarchical Patch Dynamics (HPD)  
(*Wu and Loucks 1995*)

- HPD explicitly integrates *hierarchy theory* with *patch dynamics*, and provides a conceptual and operational framework for linking pattern, process, and scale in heterogeneous landscapes.
- Clean model decomposition allows linking across disciplines as well as scale.
- Fully runtime polymorphic.
Hierarchy Theory
*(Simon 1962)*

- Focuses on top-down constraints and driving functions

Cedric Ratez, et al. (2007)
Patch Dynamics
(Pickett and White 1985)

- Focuses on spatial configuration and heterogeneity
Unit-models, Transport-models and Neighborhoods

Unit-models:

Model a semi-closed system
Know nothing about the outside world
Contain state information
Typed
Unit-models, Transport-models and Neighborhoods

Transport-models:
- Used to connect two unit-models
- Stateless by convention
- Connectivity defined by neighborhood rules
- Directed arc defined by model types
Unit-models, Transport-models and Neighborhoods

Neighborhoods:
- Implicit (4-cell, 8-cell)
- Explicit
- Anisotropic
Examples:

Urban growth modeling with Cellular Automata
Fluvial geomorphology linked with alternative vegetation models
Forest fire dynamics
Run-time polymorphism
Example: Urban Growth (CA)

$P_{\text{change}} = f(\text{local rules, domain of influence, ownership})$

1995 Land Use Map (Observed)

1995 Land Use Map (Simulated)

2030 Land Use Map (Simulated)

Wu & David 2002
Example: Linking
CA Braided Stream Model
Vegetation Succession

- Cellular automata based on routing water and sediment along a regular grid.
- Lateral movement accommodates bank erosion

UD - undisturbed
0 - recently disturbed
OW - open water
GR - bare gravel
H - herbaceous wetlands
SV - popular/willow seedlings on gravel
CW - willow saplings
W - mature willow
CS - cottonwood/poplar with shrubs
CY - young cottonwood
CO - over-mature cottonwood
SG - shrubs and grassland
Example: Linking CA Braided Stream Model

Vegetation Succession

- Cellular automata based on routing water and sediment along a regular grid.
- Lateral movement accommodates bank erosion
- Plant recruitment and growth model
- Non-linear feedbacks to geomorphic processes as a function of stand structure (density and basal area)
Example: Fire Dynamics

Anisotropic spread of fire - gray burned, black burning
Example: Run-time Polymorphism

Overloading models at runtime provides mechanisms to model dynamic hierarchies.

Original model
Conversion even cause the unit-model to be decoupled from the system
Temporal transport-model data-mines old unit-model to parameterize new one
New unit-model
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