The Applicability of Field Theories in The Population Sciences

MPDE 2017

Based on work by James Wilsenach, Pietro Landi & Cang Hui

7 September

Wilsenach, J., Landi, P., & Hui, C. (2017). Evolutionary fields can explain patterns of high-dimensional complexity in ecology. Physical Review E, 95(4), 042401.

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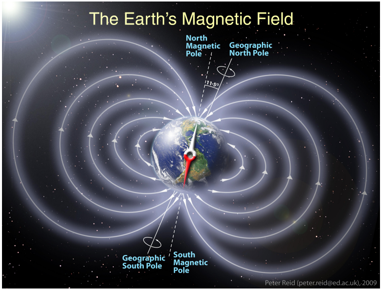
The Field Concept in Physics

- Creates action at a distance
- Is pervasive
- Events are co-dependent and multi-directional
- Particles as persistent events

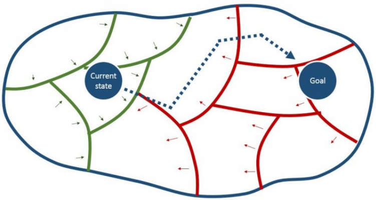


[NASA, 2017]

The Field Interpretation of Sociological Change

- Dynamic
- Driven by motivation
- Consistent Universal Framework
- Qualitative
- Networks similar to Ecology

A depiction of a life space, reflecting Kurt Lewin's field theory



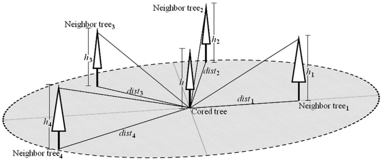
Adapted from Burnes & Cook (2013), Kurt Lewin's Field Theory: A Review and Re-evaluation, International Journal of Management Reviews, Vol. 15, 408–425
www.sidewaysthoughts.com

Relationships Between Tree Growth & Spacing

- Familiar inverse square law

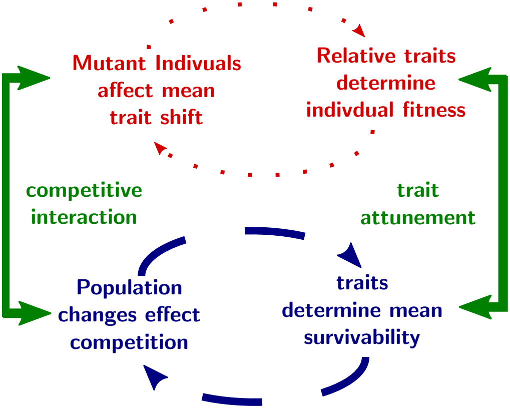
Relationships Between Tree Growth & Spacing

- Familiar inverse square law
- static predictors
- widely used



[Contreras et al., 2011]

What We Mean by Evolutionary Dynamics



Evolution as a Dynamic Field

Evolution as a Dynamic Field

1. An Evolutionary Field Φ depends locally on:
   - Interaction frequency $m_i m_j$
   - ecological relationships k_{ij}
   - trait attunement $\frac{k_{ij}}{d_{ij}^2}$

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2. Φ Influences
   1. Trait space topology
   2. trait attunement
   3. community composition

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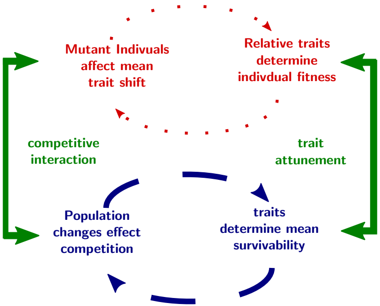

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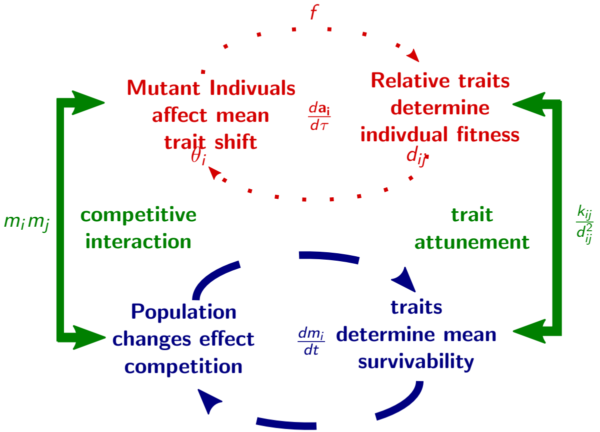
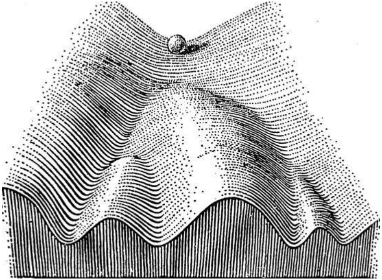


Trait Space Topology

Trait Space Topology

- many possibilities
- assortative selection: $d_{ij}^2 = e^{-||\mathbf{a_i}-\mathbf{a_j}||^2}$
  - not explosive
  - versatile

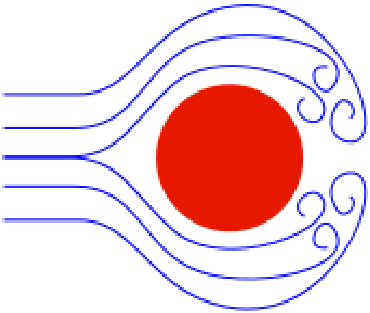


[Goldberg et al., 2007]

Constraints on Evolutionary Acceleration

Constraints on Evolutionary Acceleration

- mutation pool limits rapid adaptation
  - $\theta_i = \mu_i m_i$
  - versatile
- drags on evolution
  - $f \propto v_i^2$
  - generational/spatial
  - terminal velocity



Field & Motion Equations

$$\boldsymbol{\Phi}_{\mathbf{i}} = \sum_{j=1}^{N} \frac{k_{ij} m_i m_j}{d_{ij}^2} \mathbf{u}(\mathbf{a_j}, \mathbf{a_i}) \tag{1}$$

$$\frac{d^2 \mathbf{a_i}}{d\tau^2} = \theta_i \left[\sum_{j=1}^{N} \frac{k_{ij} m_i m_j}{d_{ij}^2} \mathbf{u}(\mathbf{a_j}, \mathbf{a_i}) - \mathbf{f_i} \right] \tag{2}$$

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Fox and Rabbit Case Study

k_{ij}			
	$k_{11} < 0$ $\leftarrow\rightarrow$	$k_{12} < 0$ $\leftarrow\leftarrow$	$k_{1s} > 0$ $\rightarrow\bullet$
	$k_{21} < 0$ $\rightarrow\rightarrow$	$k_{22} < 0$ $\leftarrow\rightarrow$	$k_{1s} = 0$

Population Dynamics

$$\frac{dm_1}{dt} = \left[r_1 + k_{11} m_1 + \frac{k_{12}}{d_{12}^2} m_2 + \frac{k_{1s}}{d_{1s}^2} m_s \right] m_1 \quad (3)$$

$$\frac{dm_2}{dt} = \left[r_2 + k_{22} m_2 + \frac{k_{21}}{d_{21}^2} m_1 \right] m_2 \quad (4)$$

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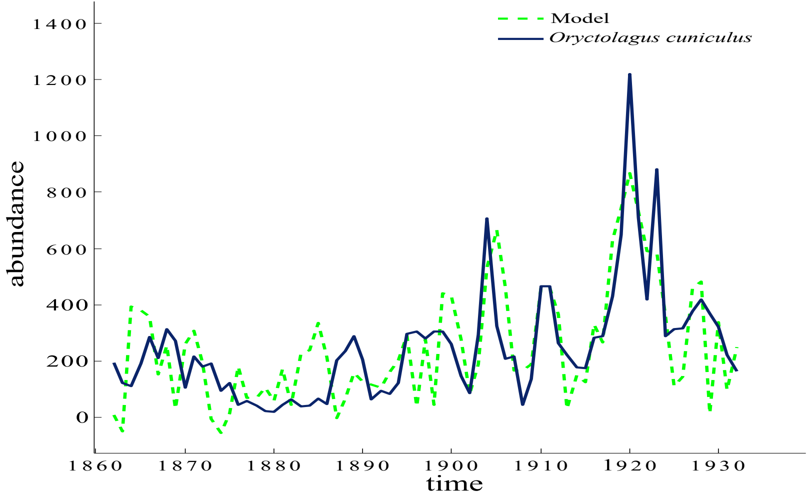
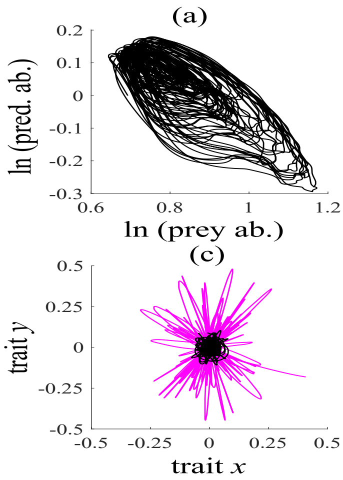
Model Fit to Rabbit Data

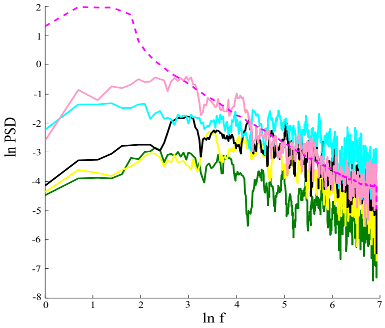


General System Behaviour



Properties of Pink Noise

- everywhere in ecology
- long memory
- fractal dimension $\frac{2}{\alpha - 1}$



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