Team ALife

Towards an Artificial Polytrophic Ecosystem

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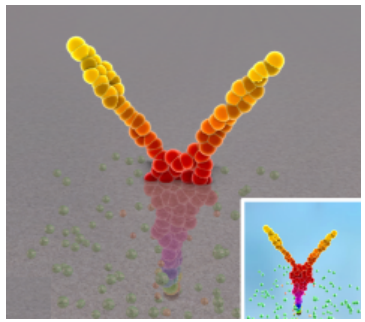
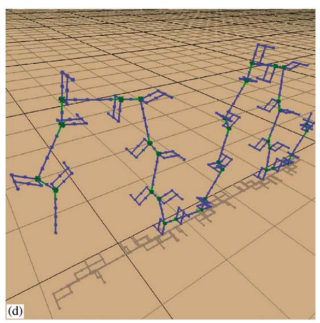
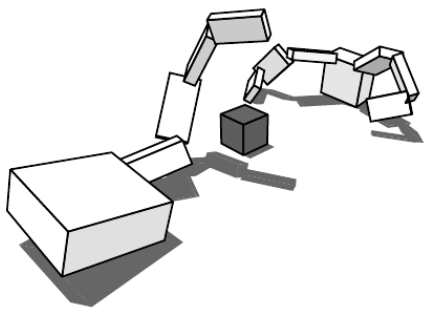
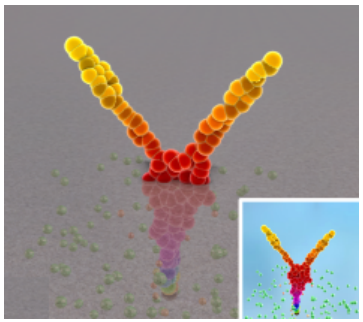
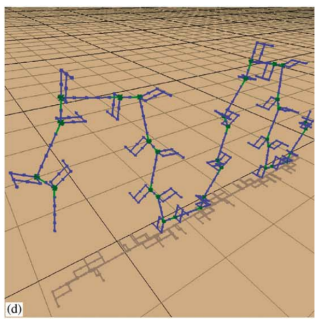
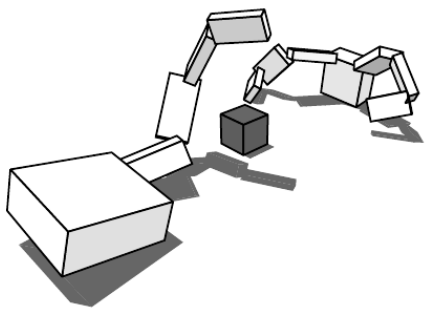
Overview

- Artificial Ecosystems
  - Morphogenetic engineering
  - Ecosystems
  - Polytrophism
- Model (A.P.E.)
- Experiments
- Future Work

Morphogenetic engineering

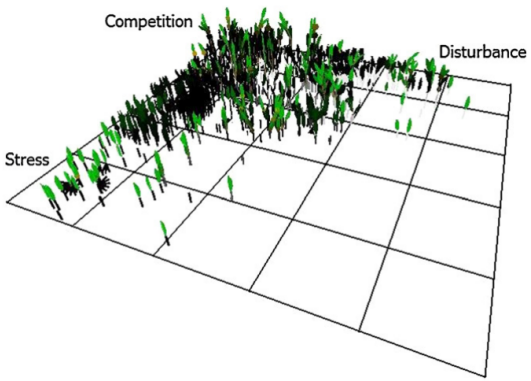
	L-System	Graphtal	GRN
Plants		∅	
	Bornhofen (2008)		Disset et al. (2016)
Animals			∅
	Hornby et al. (2001)	Sims (1994)	

Morphogenetic engineering

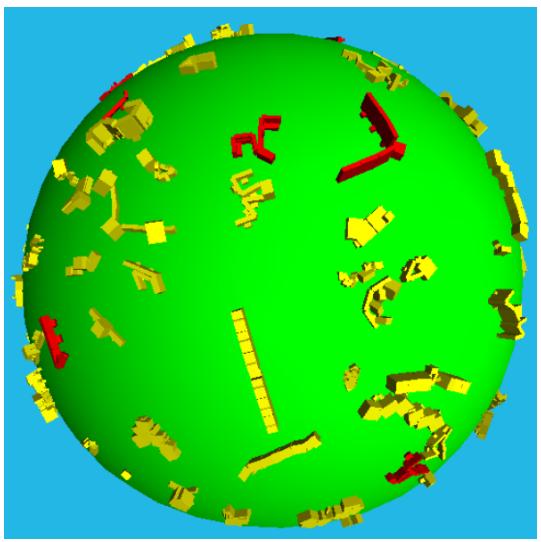
	L-System	Graphtal	GRN
Plants		∅	
	Bornhofen (2008)		Disset et al. (2016)
Animals		A.P.E. 	∅
	Hornby et al. (2001)	Sims (1994)	

Ecosystems

- Accurate prediction tools
- Art productions
- Either focused on plant (a) or animals (b).



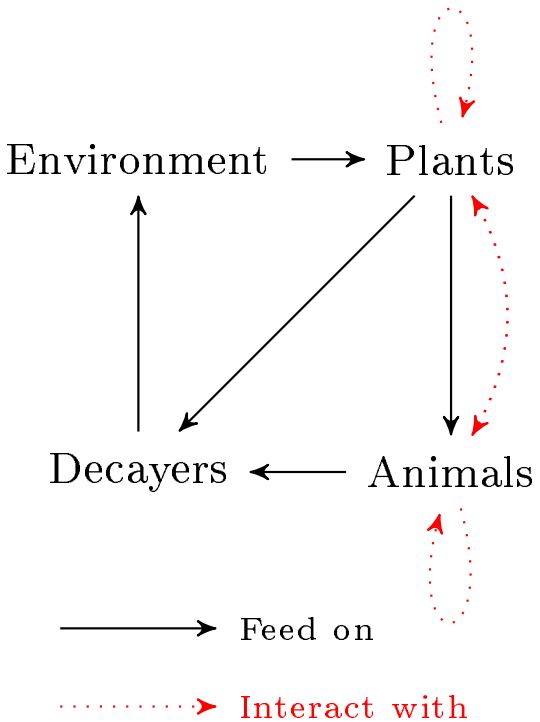
(a) Bornhofen et al. 2011 - *Ecological Modelling*



(b) Miconi 2008 - *2008 IEEE Congress on Evolutionary Computation, CEC 2008*

Polytrophism

Autotrophism + Heterotrophism



Studying interactions:

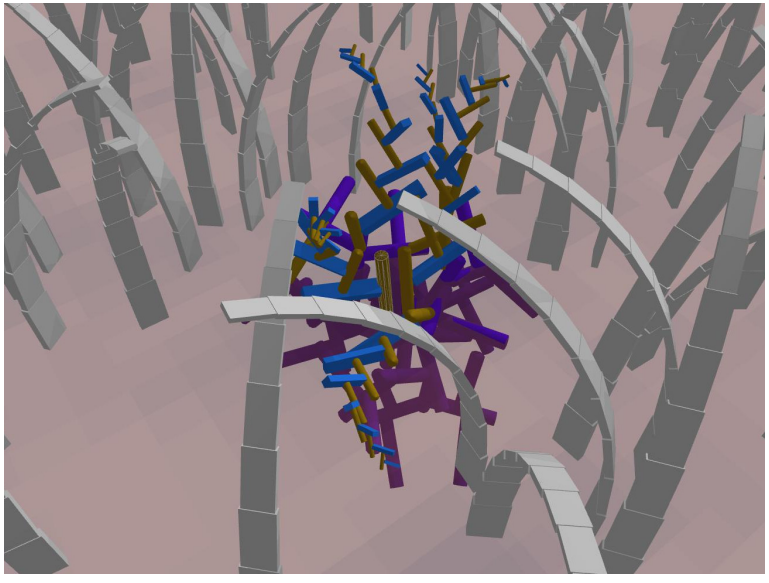
- Plants/Animals
- Predation emergence
- Environment → Evolution

Overview

- Artificial Ecosystems
- Model (A.P.E.)
  - Environment
  - Growth model
  - Metabolism
- Experiments
- Future Work

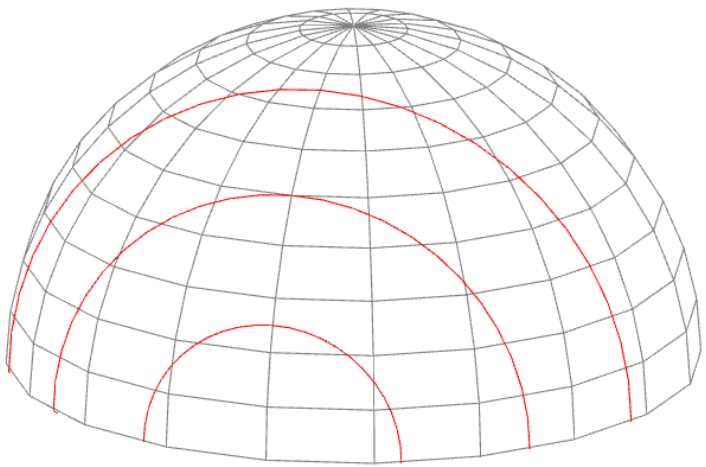
Environment

- 3D physics world (Bullet)
- Dynamic light modeling
- Simplified water cycle



Environment

Light



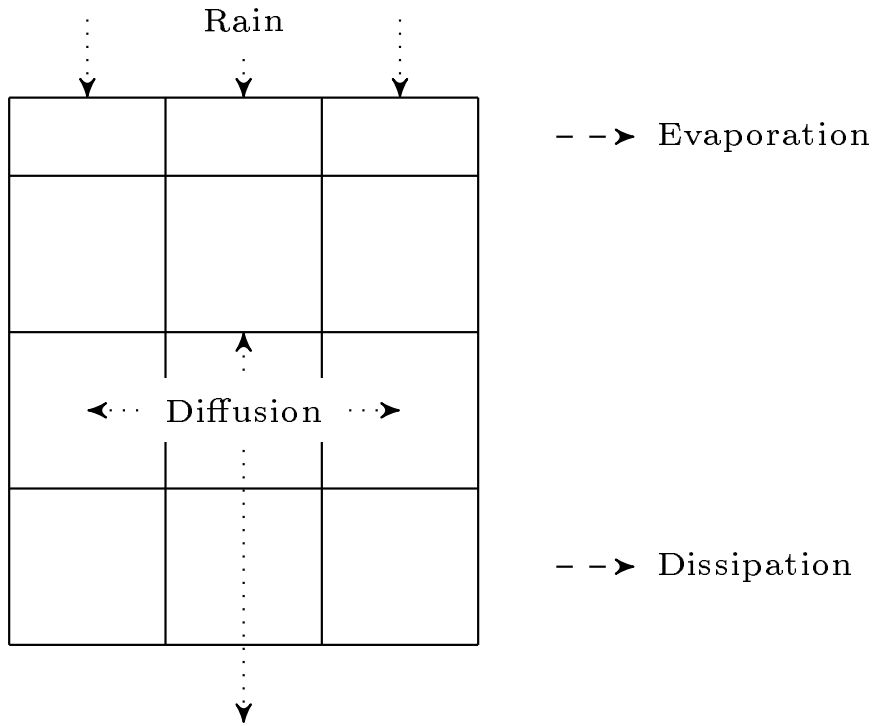
Sun path

- Alternance of abundant and limited light
- Day/night cycle forces use of reserves
- Effect on ground temperature is pending

Environment

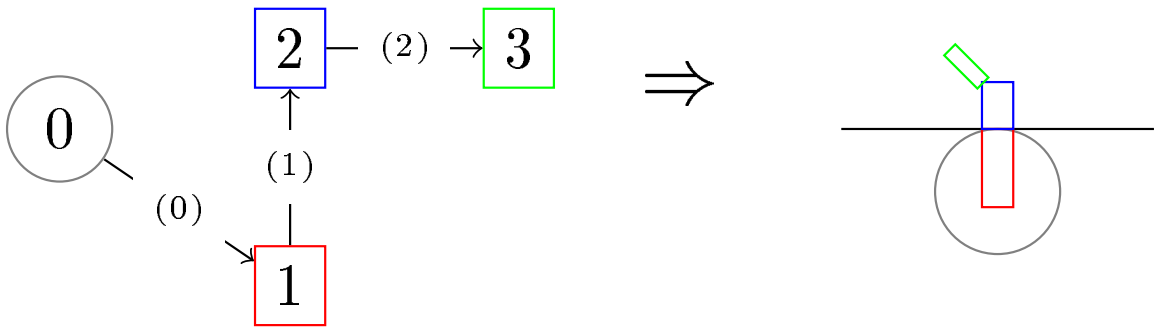
Water

VN: Von-Neuman neighborhood
$V_{i,j}$: Water stored in voxel (i,j)
S_j: Saturation at depth j
k_d: Diffusion rate



$$\frac{dV_{i,j}}{dt} = min(S_j, \sum_{(i',j')\in VN} k_d 2^{j'} V_{i+i',j+j'}) - \sum_{(\_,j')\in VN} k_d 2^{j'} V_{i,j}$$

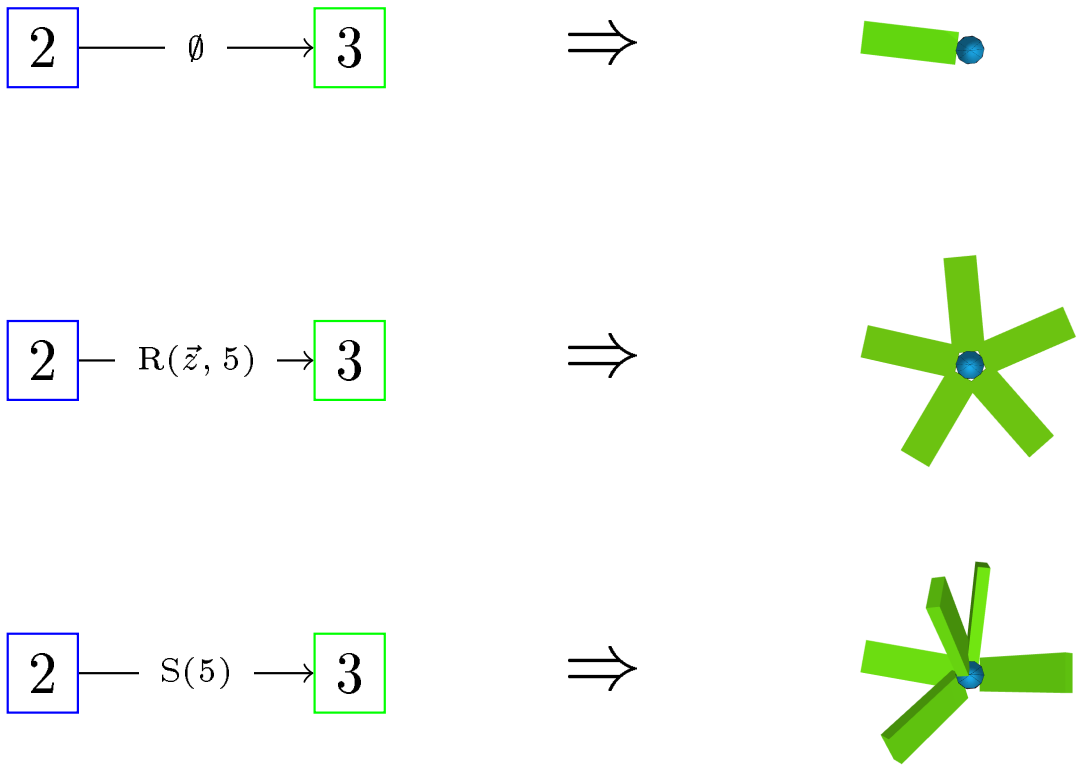
Growth model



Nodes
Dimensions
Shape
Skill
Growth
Allocation
Survival

Links
Direction
Orientation
Recursivity
Effect
Scale

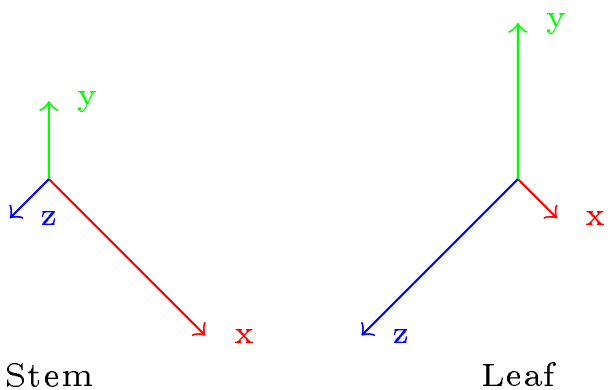
Growth model



Growth model

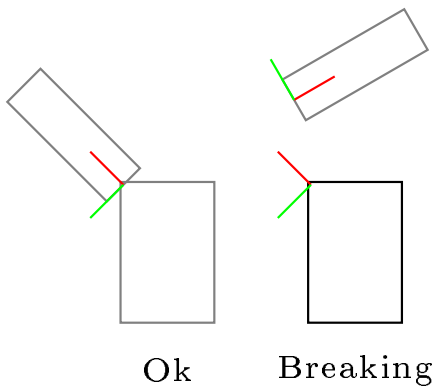
Organ growth

- Reserves
- Growth speeds
- Maximal/Relative scales



Constraints

- Fixed 6DoF
- Emergent properties
- Physical plausibility

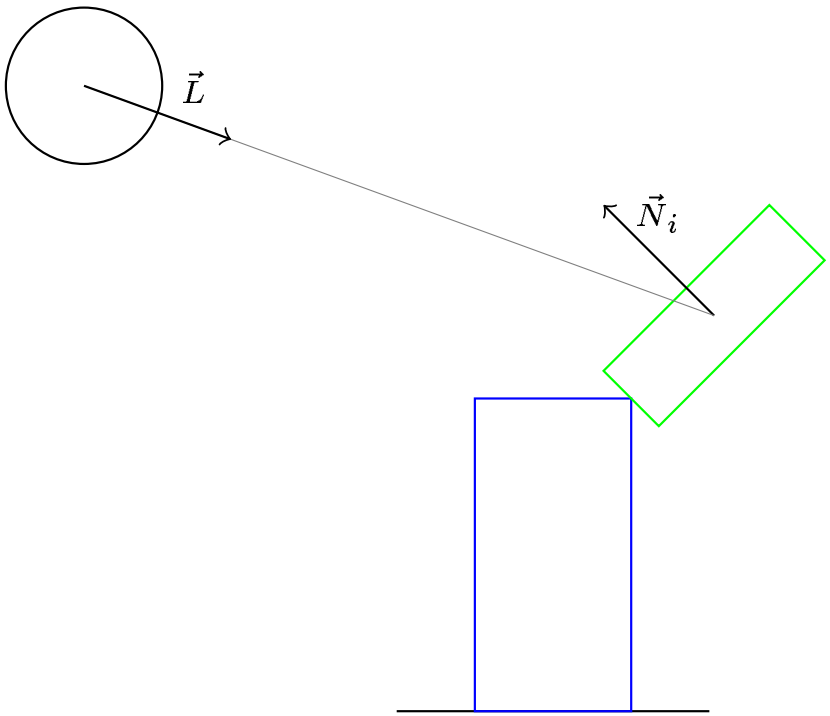


Metabolism

- Keys to survival: Water & Glucose
- Seed provides initial reserves
- Emergence of 'foraging' strategies

Metabolism

Photosynthesis



i: Organ
e: Element (Water, Glucose)
V_i: Organ's volume
a_i^e: Allocation value
R_i^e: Reserves in element e
A_i^e: Available amount
S_i: Photoreceptive surface
$\vec{N}_i$: Surface's normal vector

$$A_i^e = max(0, R_i^e - a_i^e V_i)$$
$$\frac{dR^{glucose}}{dt} = \sum k_p A_i^{water} min(0, S_i \vec{L}.\vec{N}_i)$$

Metabolism

Diffusion

Req_i^e: Requested amount of element e

k_t: Nutrients diffusion speed constant

$$Req_e^i = a_i^e(V_i - R_i^e)$$

$$\frac{dR_i^e}{dt} = (\sum_j A_j^e)Req_i^e - k_t A_i^e$$

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- Artificial Ecosystems
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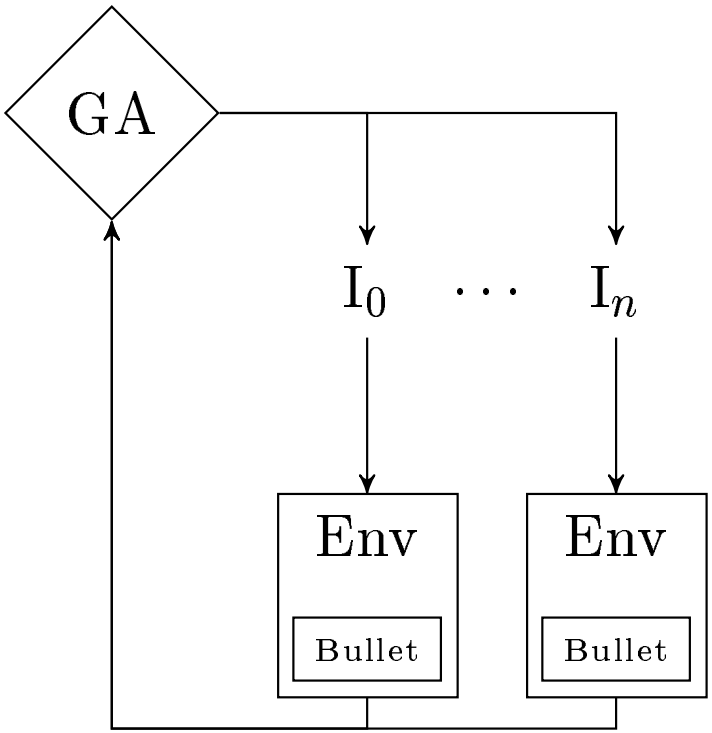
- Experiments
  - Genetic algorithm
  - Survival
  - Competition
- Future Work

Genetic algorithm



$$Fitness = \frac{2\sum iG_i}{N(N-1)}$$

- N = 60000 (2 years)
- G_i: Glucose production

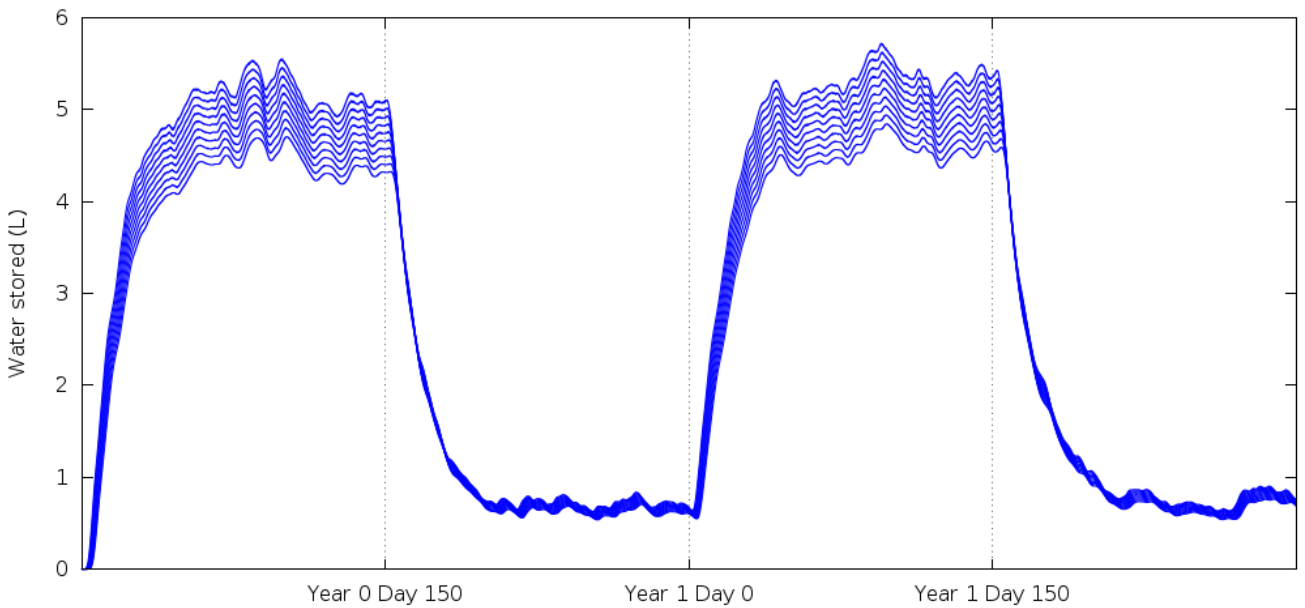
Novelty:

- Production
- Territory

Performed of an Intel Xeon CPU E5-2660 v3 @ 2.60GHz x 20

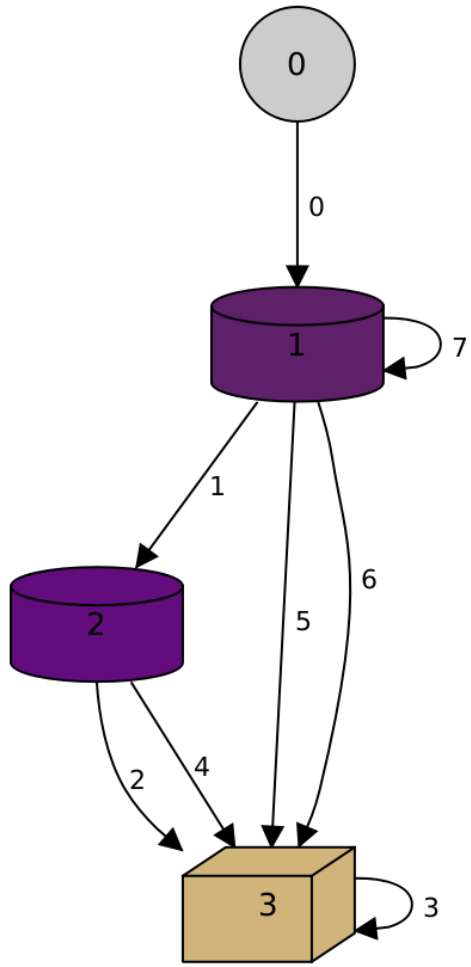
Survival

- Empty environment (no competition)
- Short days, light $\in [\pi/8; 3\pi/8]$
- Moderate precipitations



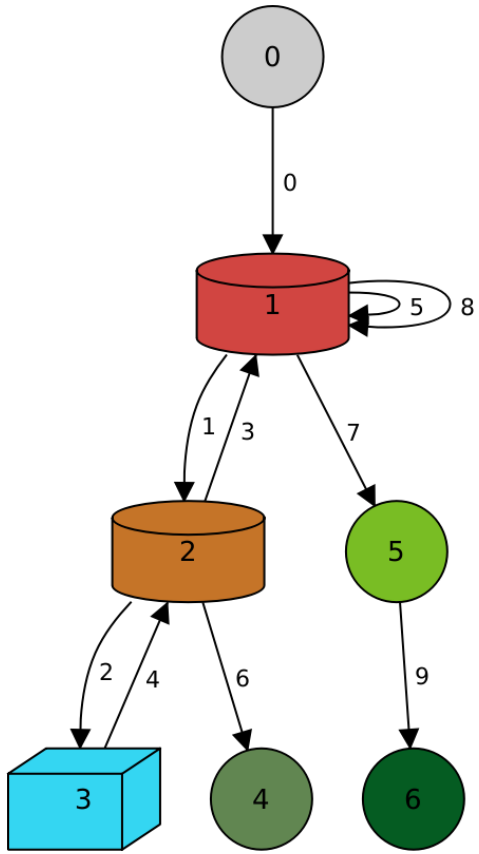
Survival

Tillers production



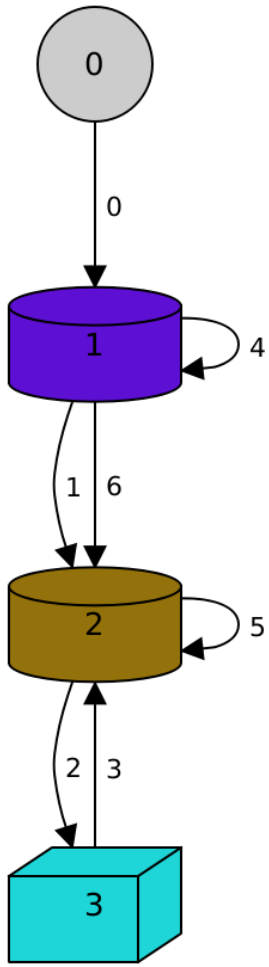
Survival

Structured recursivity



Competition

Simulated vertical competition

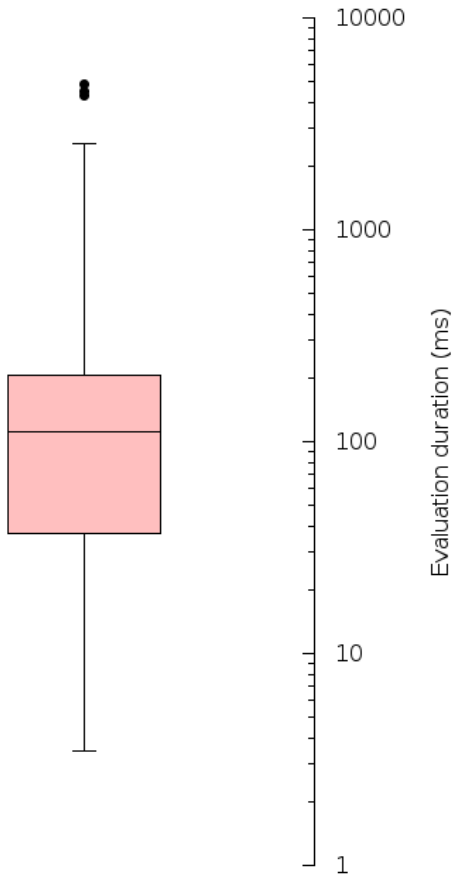


Overview

- Artificial Ecosystems
- Model (A.P.E.)
- Experiments
- Future Work
  - Physics
  - Plants growth & behavior
  - Co-evolving plants in evolving environments

Physics

- Constraints induce instabilities
- Huge CPU cost
- Lack of structural plausibility

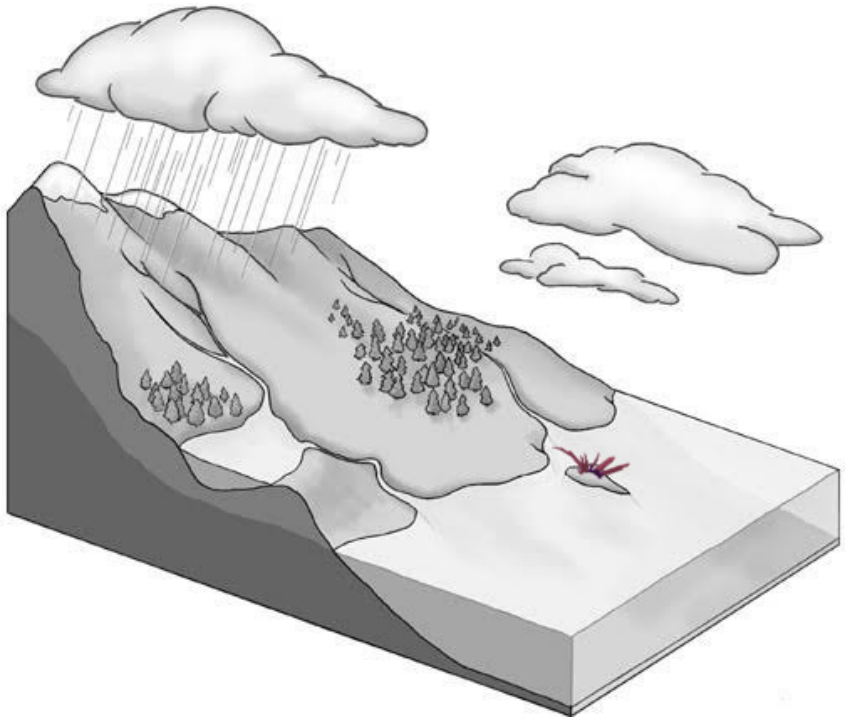


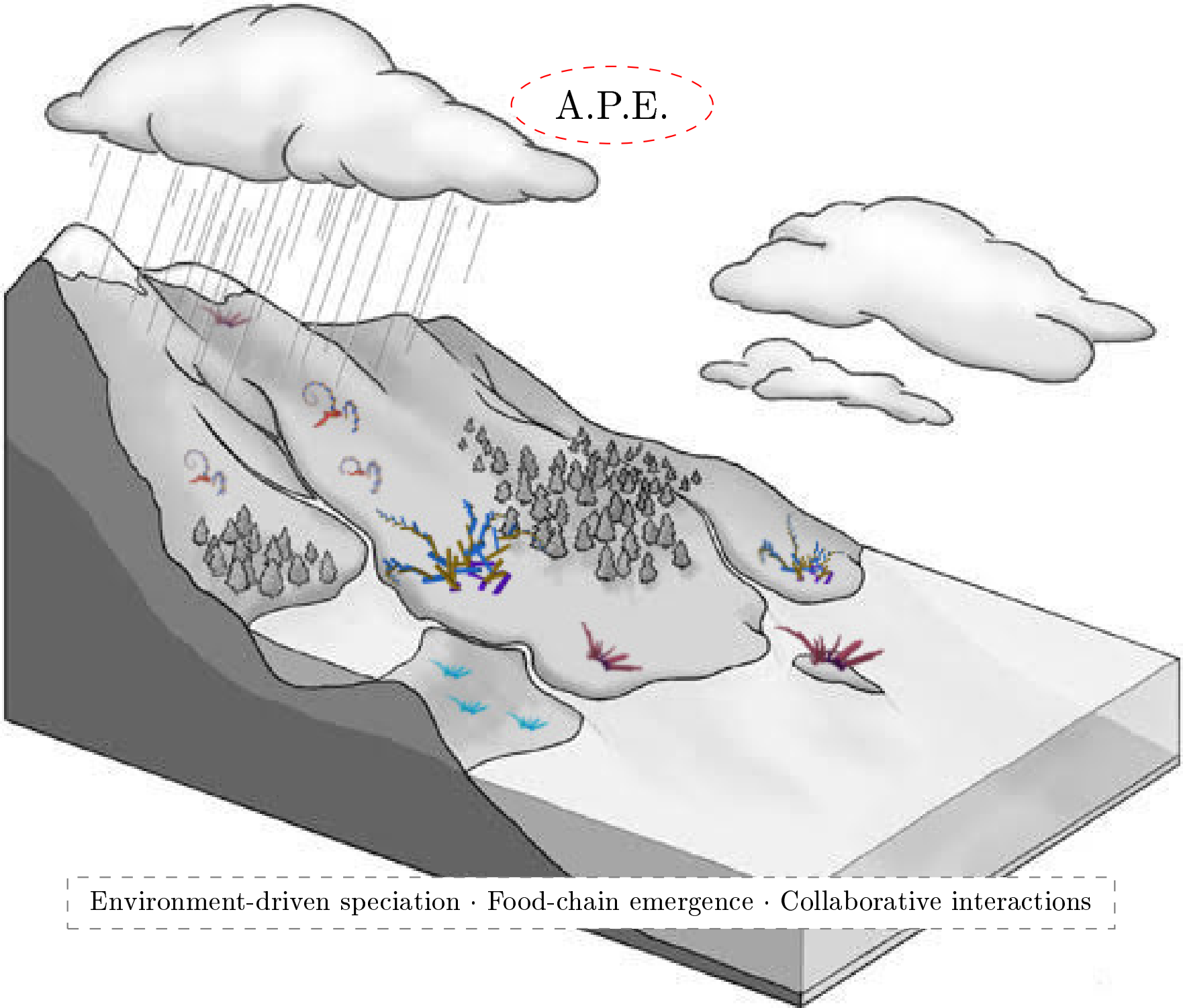
Plants growth & behavior

- Phototropism, Gravitropism, ...
- Impact of temperature
- Adding new nutrients (N, P, K, ...)

Co-evolving plants in evolving environments

- Co-evolving plants
  - Random seeds
  - Autonomous reproduction
- Evolving environments
  - Topology
  - Light/Heat intensity
  - Water sources




A.P.E.
Environment-driven speciation · Food-chain emergence · Collaborative interactions

References

S. Bornhofen, S. Barot, and C. Lattaud. “The evolution of CSR life-history strategies in a plant model with explicit physiology and architecture”. In: *Ecological Modelling* 222.1 (2011), pp. 1–10.

Stefan Bornhofen. “Emergence de dynamiques evolutionnaires dans une approche multi-agents de plantes virtuelles”. PhD thesis. 2008.

Jean Disset, Sylvain Cussat-Blanc, and Yves Duthen. “Evolved Development Strategies of Artificial Multicellular Organisms”. In: *Artificial Life, Cancún, 2016*. The MIT Press, 2016.

Gregory S. Hornby and Jordan B. Pollack. “Evolving L-systems to generate virtual creatures”. In: *Computers and Graphics (Pergamon)* 25.6 (2001), pp. 1041–1048. arXiv: arXiv:1011.1669v3.

Thomas Miconi. “Evosphere: Evolutionary dynamics in a population of fighting virtual creatures”. In: *2008 IEEE Congress on Evolutionary Computation, CEC 2008* (2008), pp. 3066–3073.

Karl Sims. “Evolving 3D Morphology and Behavior by Competition”. In: *Artificial Life* 1.4 (1994), pp. 353–372.