Institut de Recherche
en Informatique de Toulouse
CNRS - INP - UT3 - UT1 - UT2J

ReVa

Beneficial Catastrophes: Leveraging Abiotic Constraints through Environment-Driven Evolutionary Selection

Kevin GODIN-DUBOIS

On-demand pre-recorded presentation
for IEEE 2020 ALife Symposium

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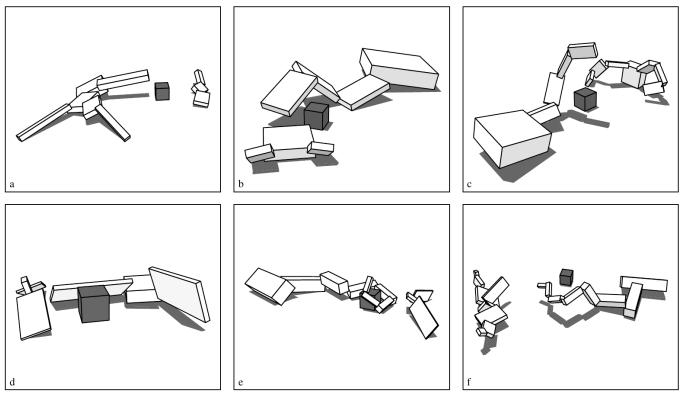
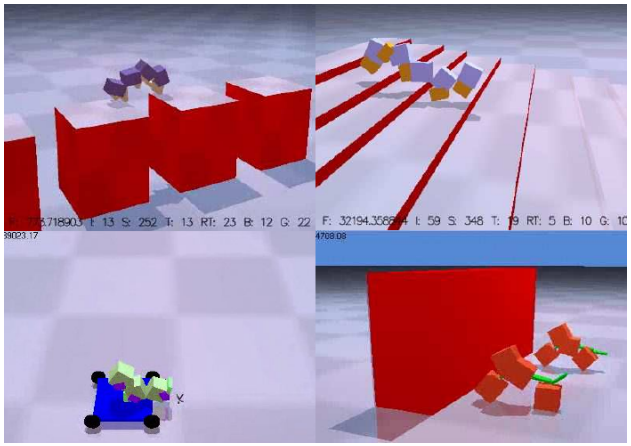
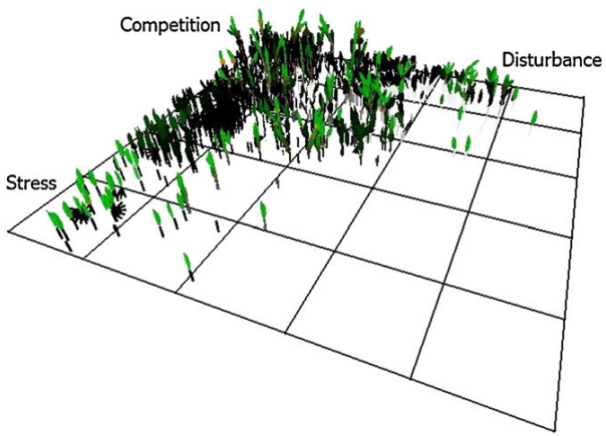
Context



Sims (1994)



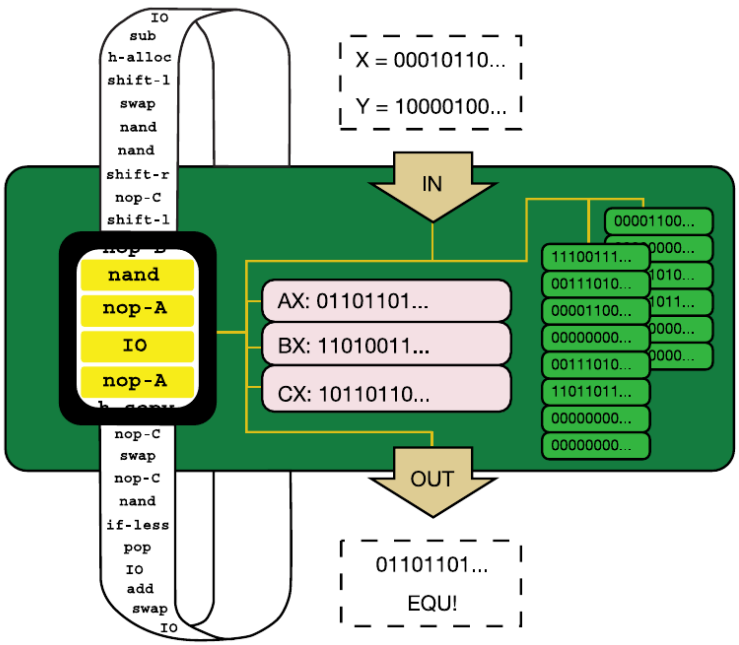
Lassabe et al. (2007)



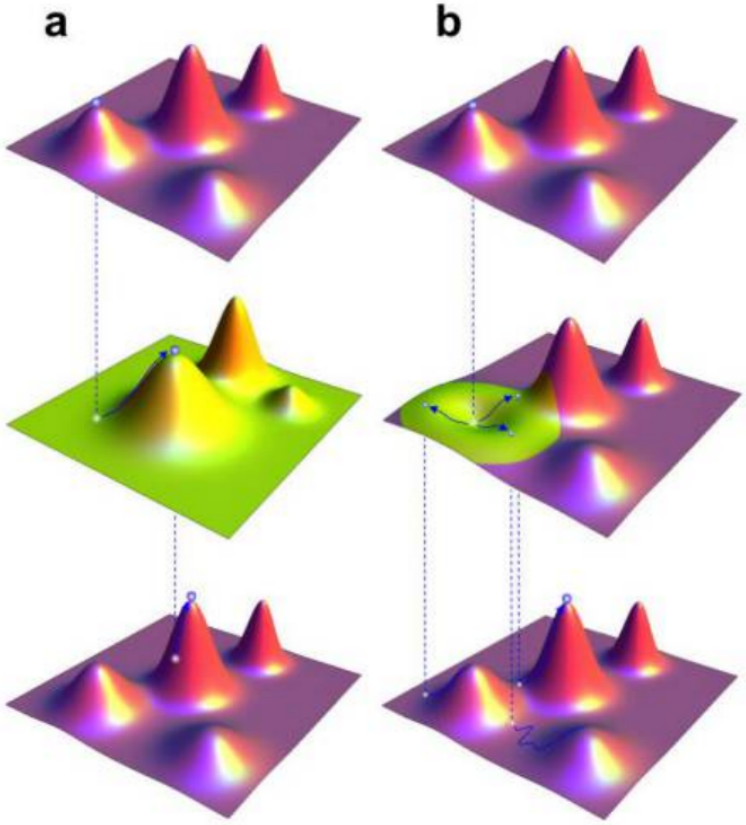
Bornhofen et al. (2011)

Eloy et al. (2017)

Context



Lenski et al. (2003)



Nahum et al. (2017)

EDEnS

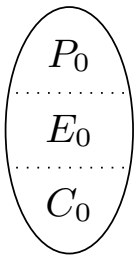
EDEnS

Environment-Driven Evolutionary Selection

- Parallel exploration of alternative "realities"
- Guided by a set of fitness functions
- Evaluating populations
- Controlling *indirectly* through environments

EDEnS

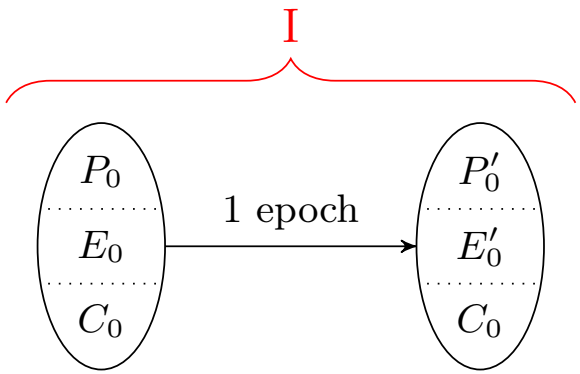
Main steps



P/P': *pop. before/after evolution*
E/E': *env. before/after variations*
C: *env. controller*

EDEnS

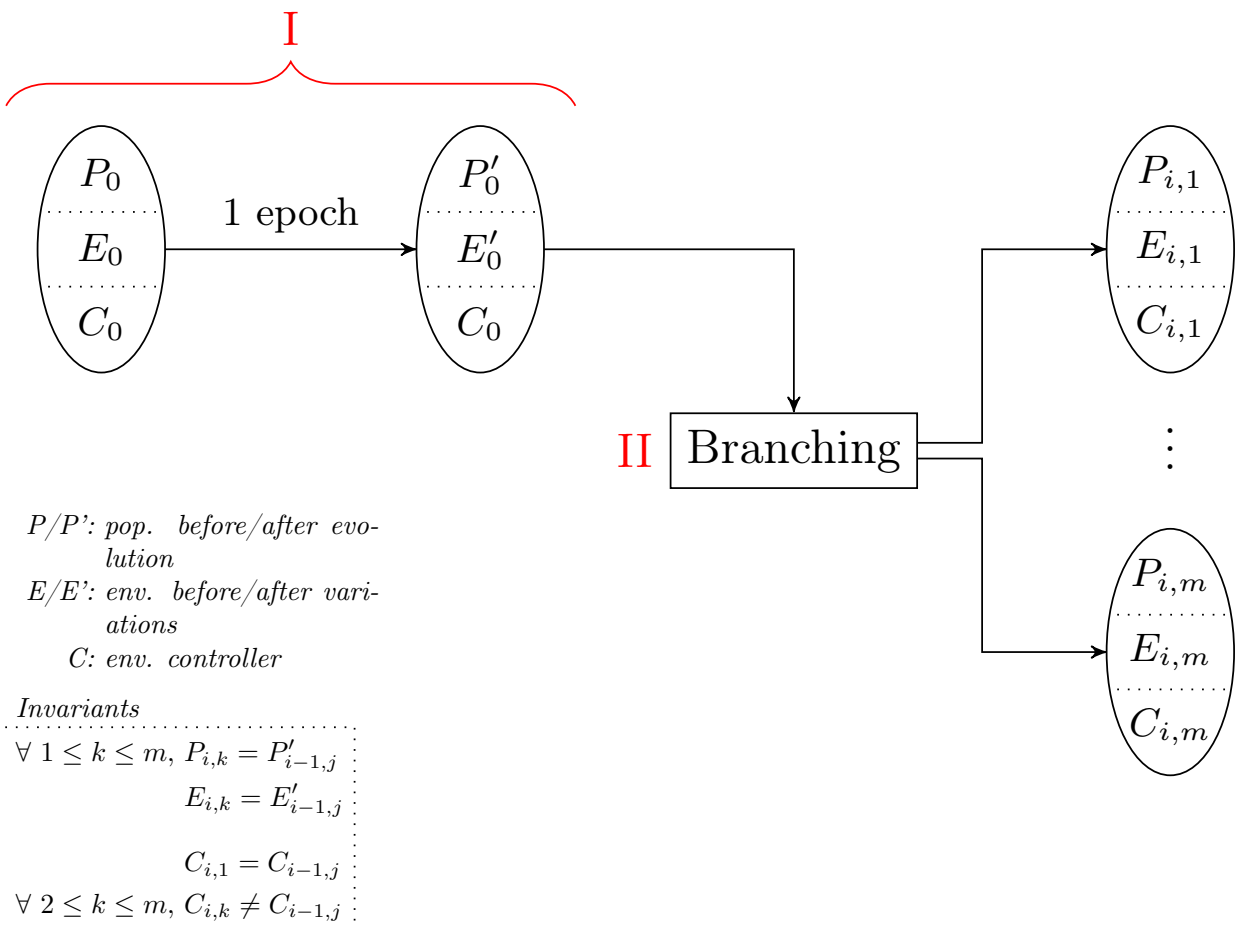
Main steps



P/P': pop. before/after evolution
E/E': env. before/after variations
C: env. controller

EDEnS

Main steps



P/P': *pop. before/after evolution*
E/E': *env. before/after variations*
C: *env. controller*

Invariants

$\forall\ 1 \leq k \leq m,\ P_{i,k} = P'_{i-1,j}$

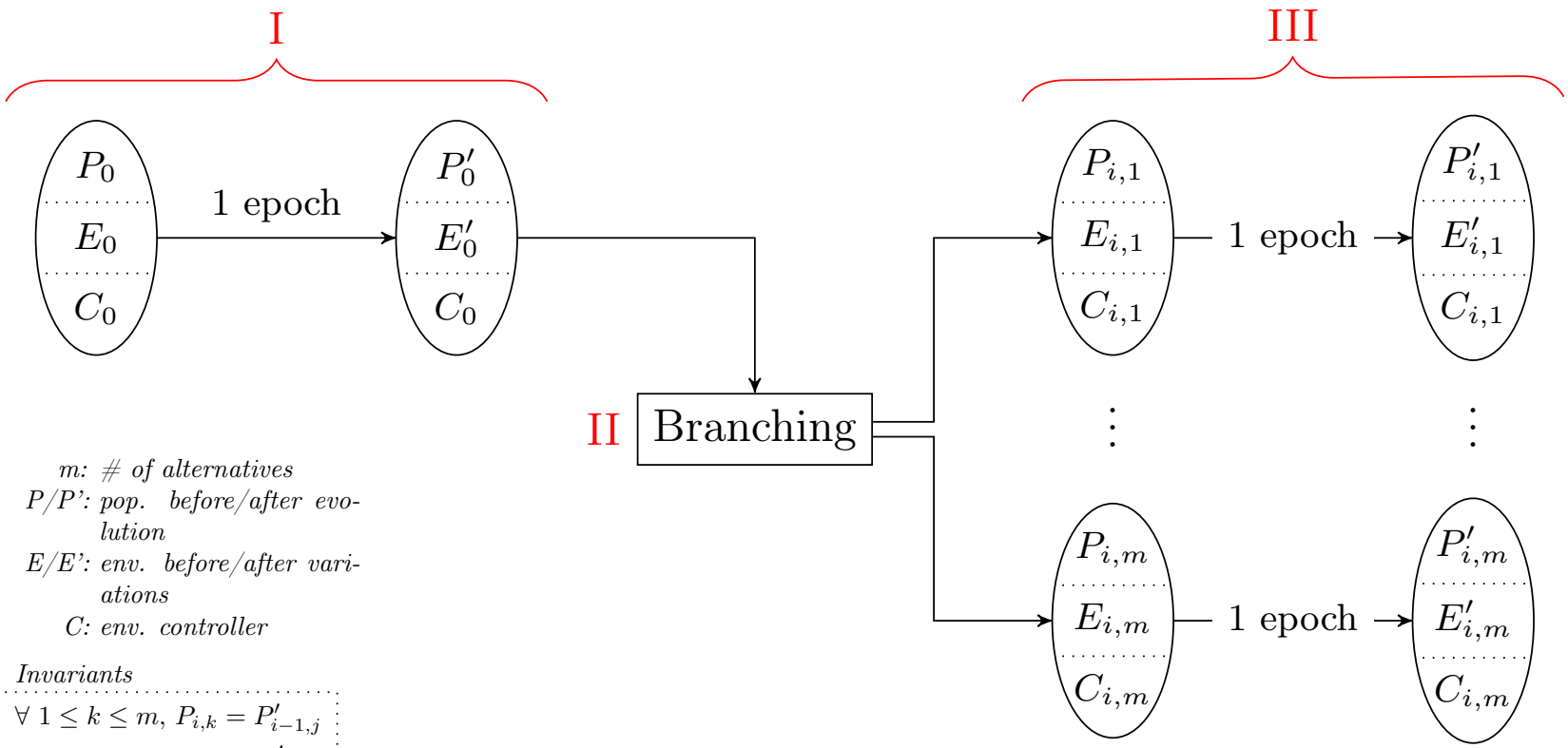
$E_{i,k} = E'_{i-1,j}$

$C_{i,1} = C_{i-1,j}$

$\forall\ 2 \leq k \leq m,\ C_{i,k} \neq C_{i-1,j}$

EDEnS

Main steps



m: # of alternatives
P/P': pop. before/after evolution
E/E': env. before/after variations
C: env. controller

Invariants

$\forall\ 1 \leq k \leq m,\ P_{i,k} = P'_{i-1,j}$

$E_{i,k} = E'_{i-1,j}$

$C_{i,1} = C_{i-1,j}$

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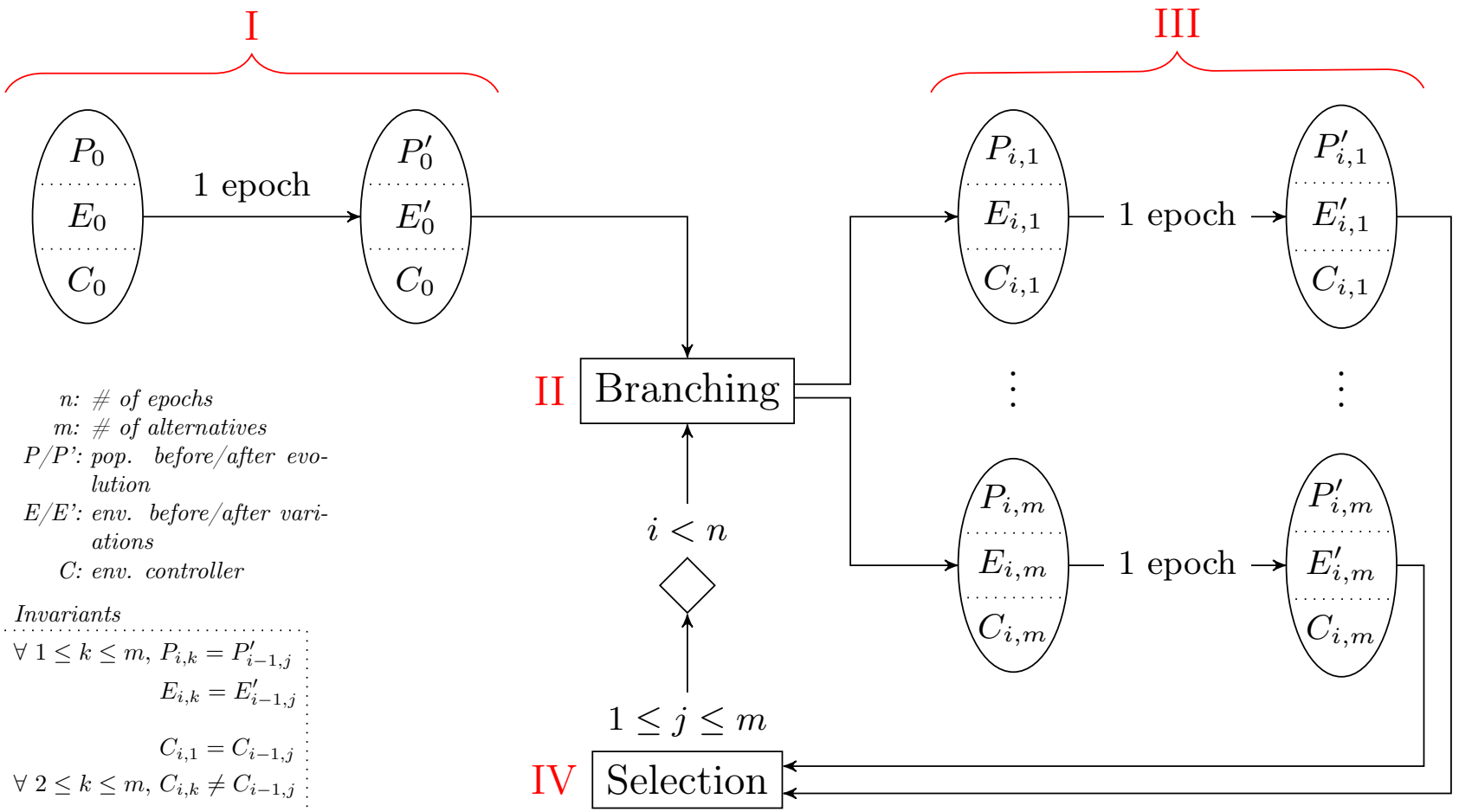
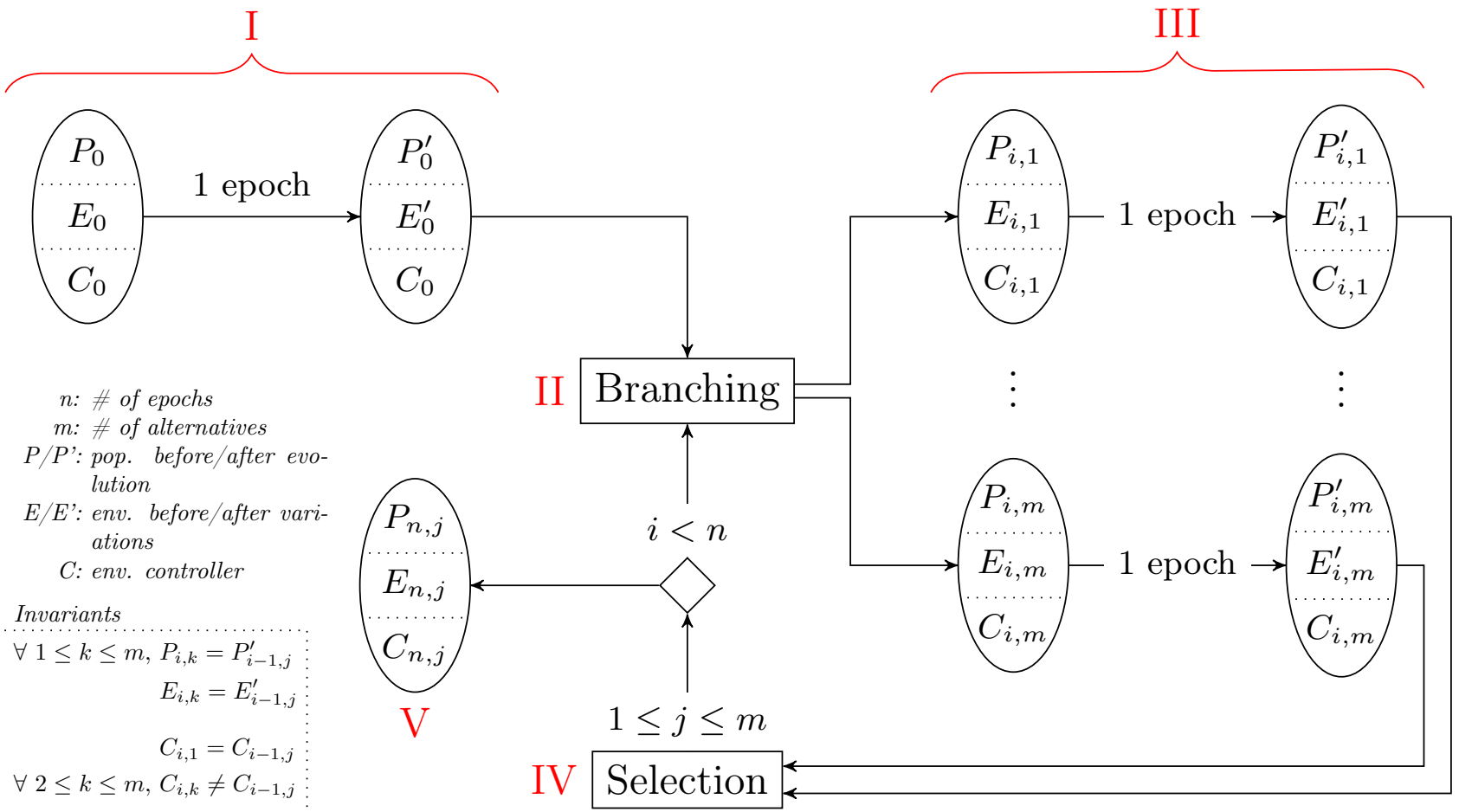
EDEnS

Main steps



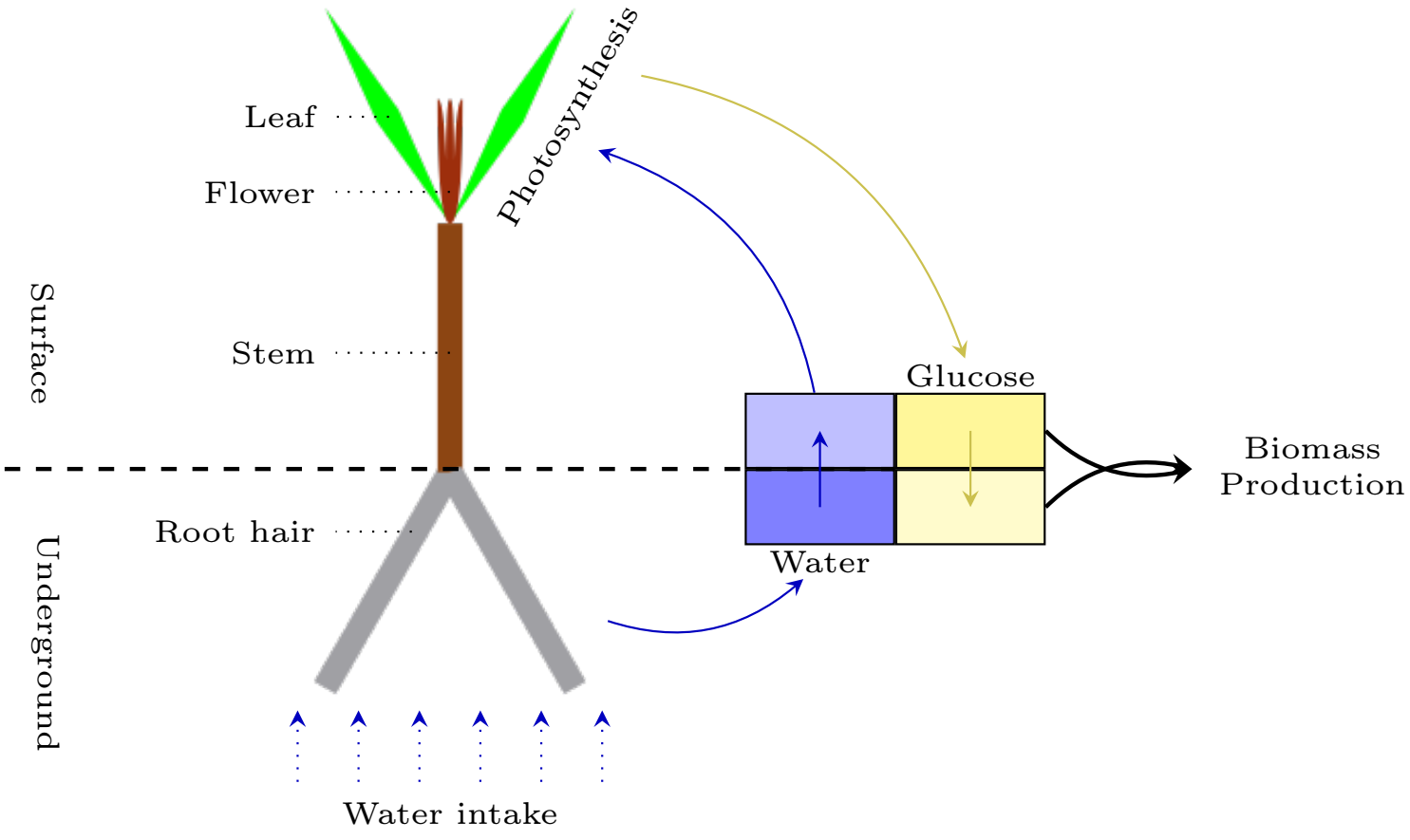
EDEnS

Main steps



Implementation

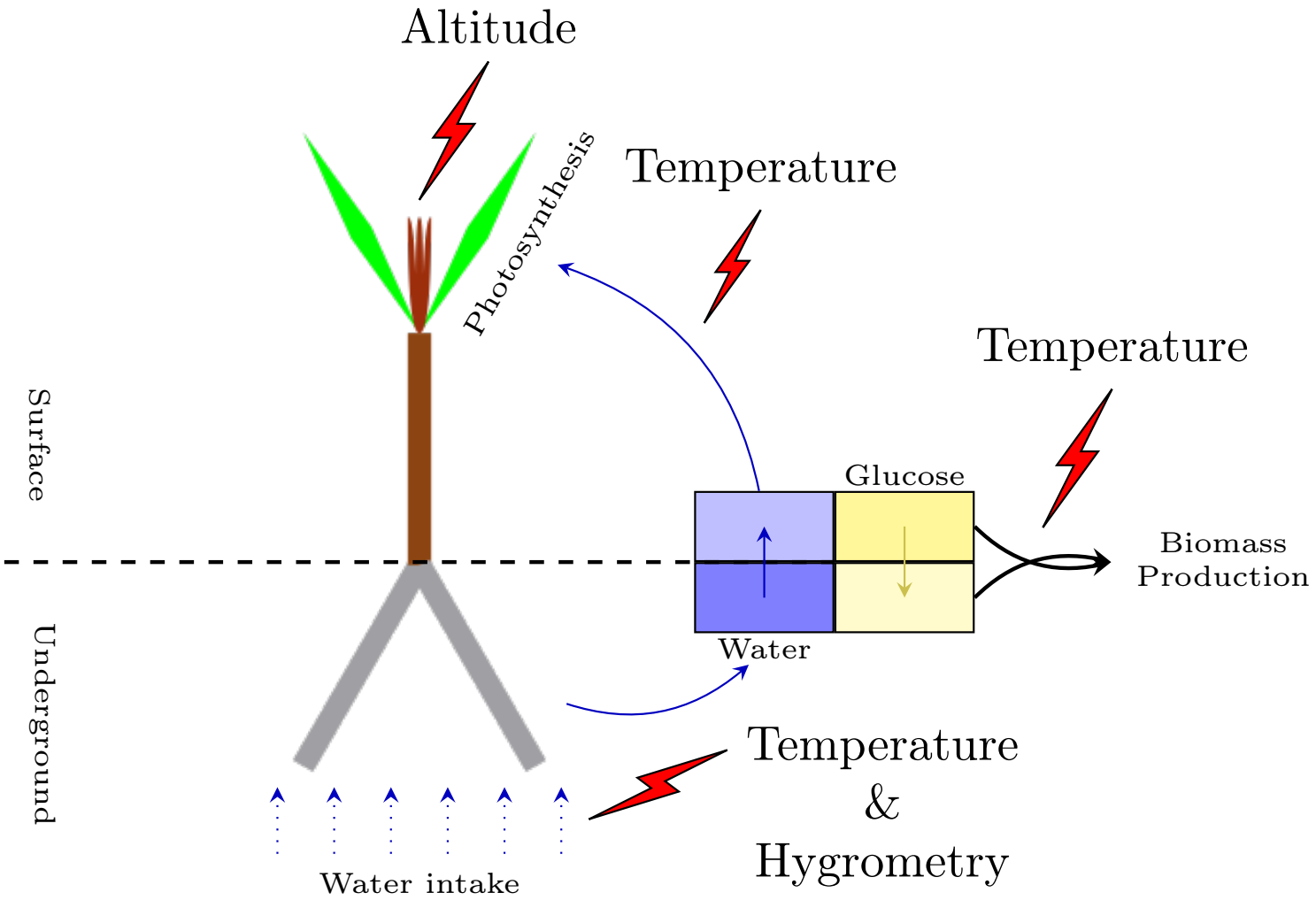
Plants



Full implementation details can be found in [3]

Implementation

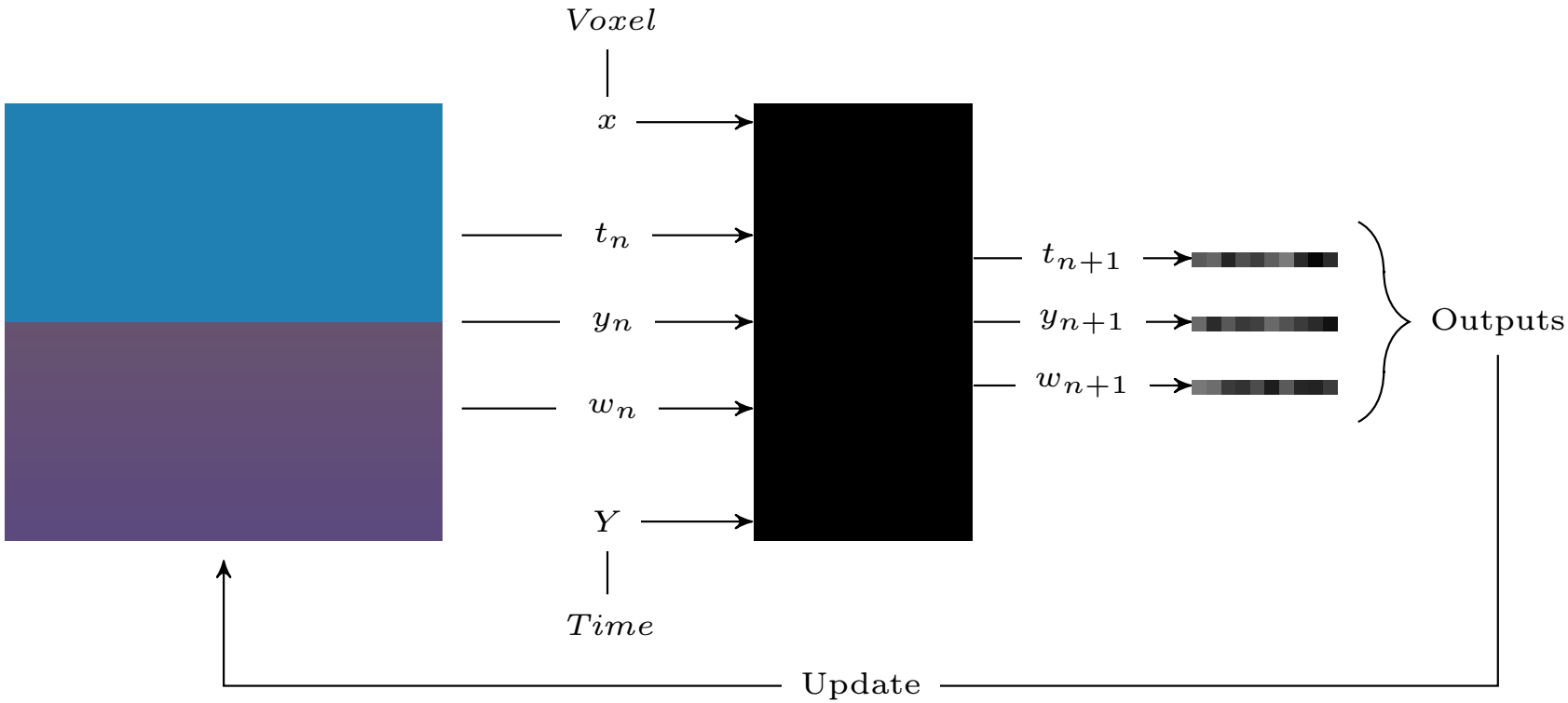
Plants



Full implementation details can be found in [3]

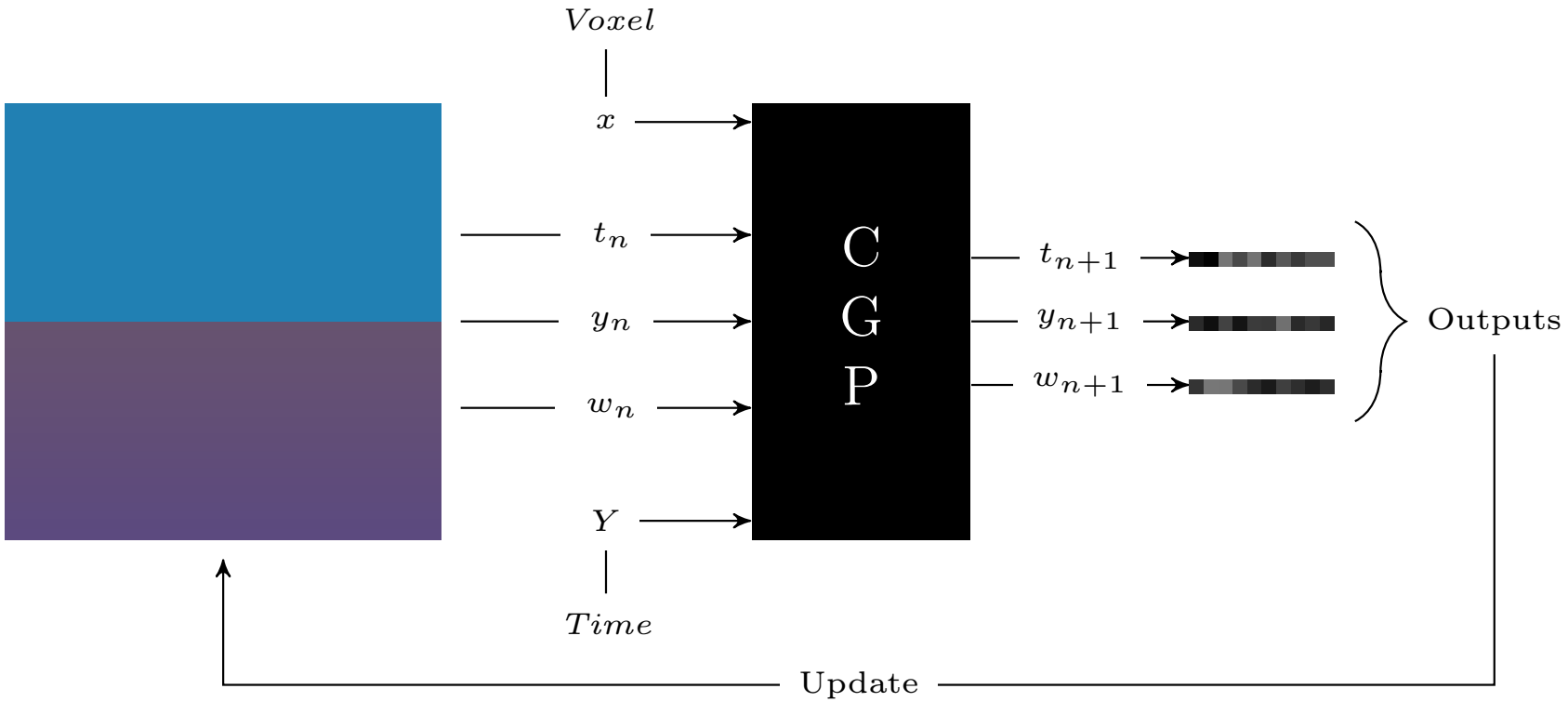
Implementation

Environment



Implementation

Environment



Promoting robustness

Promoting robustness

Evolutionary protocol

Fitness functions	
C_P	Population size
C_T	Evaluation time
F_S	Speciation patterns
F_D	Genetic diversity

Parameters	
n = 250	epochs
e = 4	years per epoch
m = 10	branching factor

Two groups:

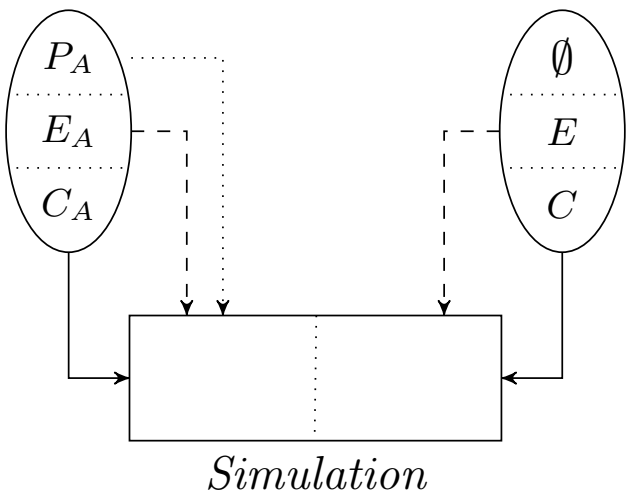
Evolved (e) uses EDEnS, 10 replicates

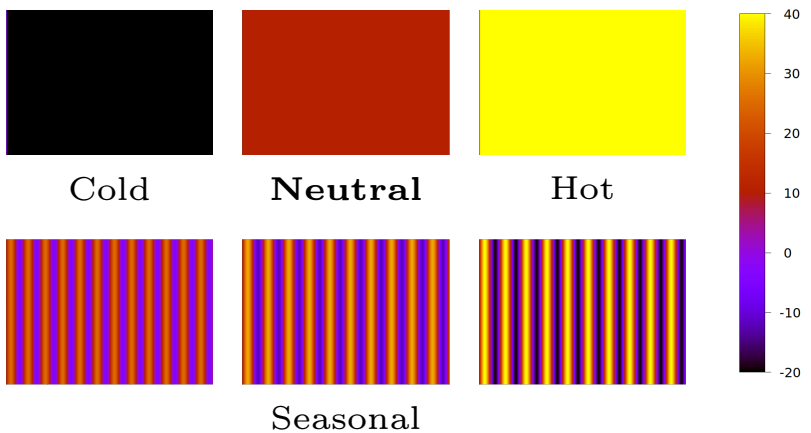
Control (c) hospitable conditions, 5 replicates

Promoting robustness

PvE

Hand-crafted right-hand side conditions

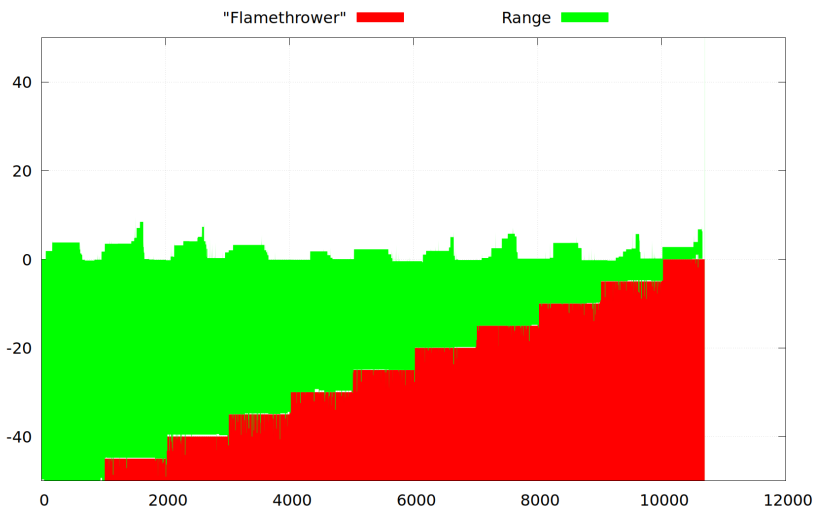




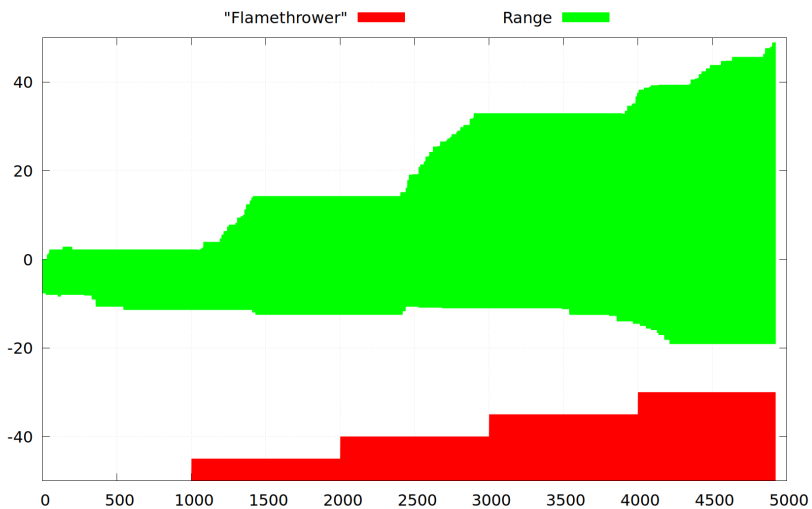
Promoting robustness

PvE

Score is the distance “traveled”



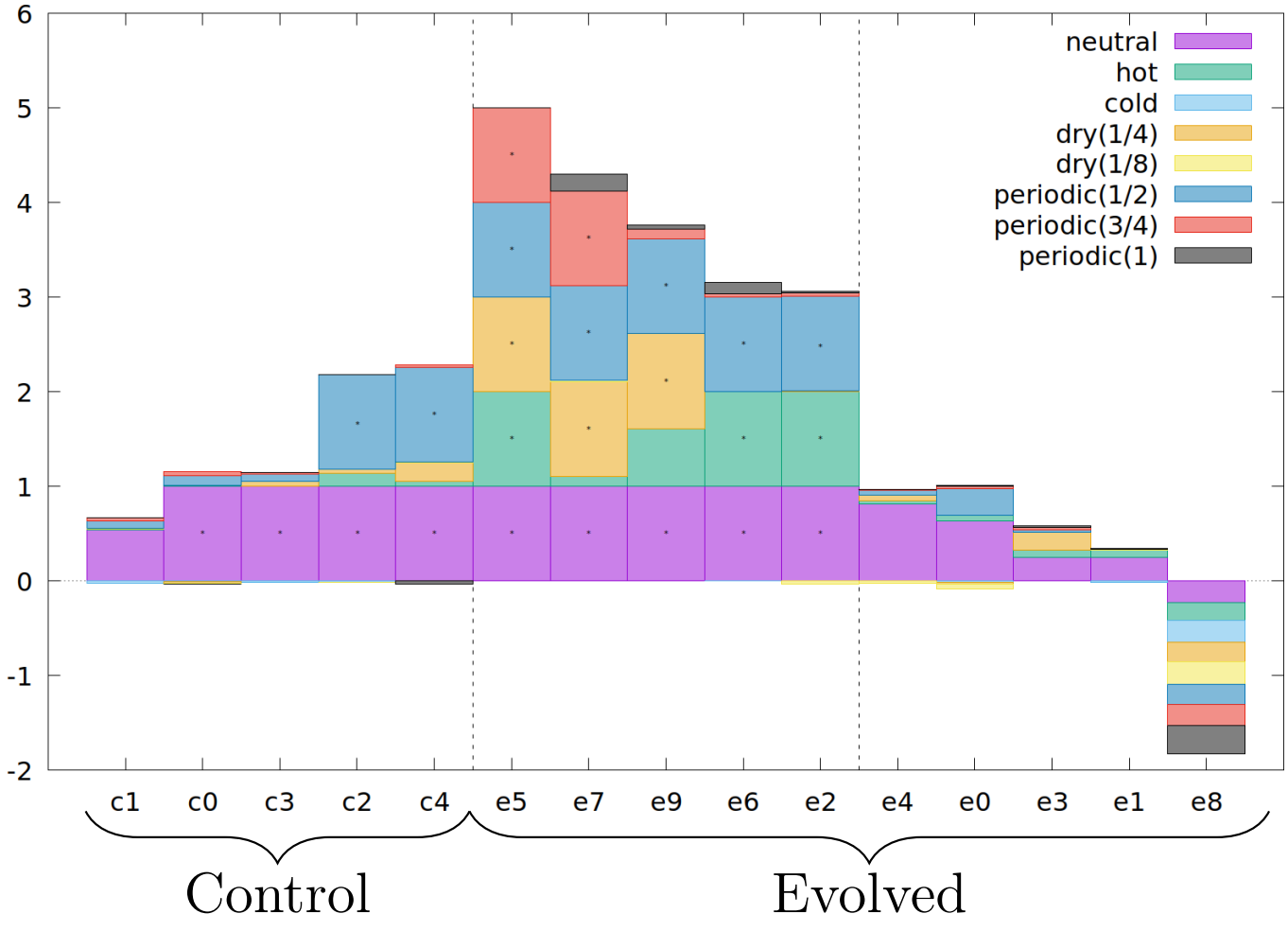
Poor performance (score = 0)



Goal reached (score = 1)

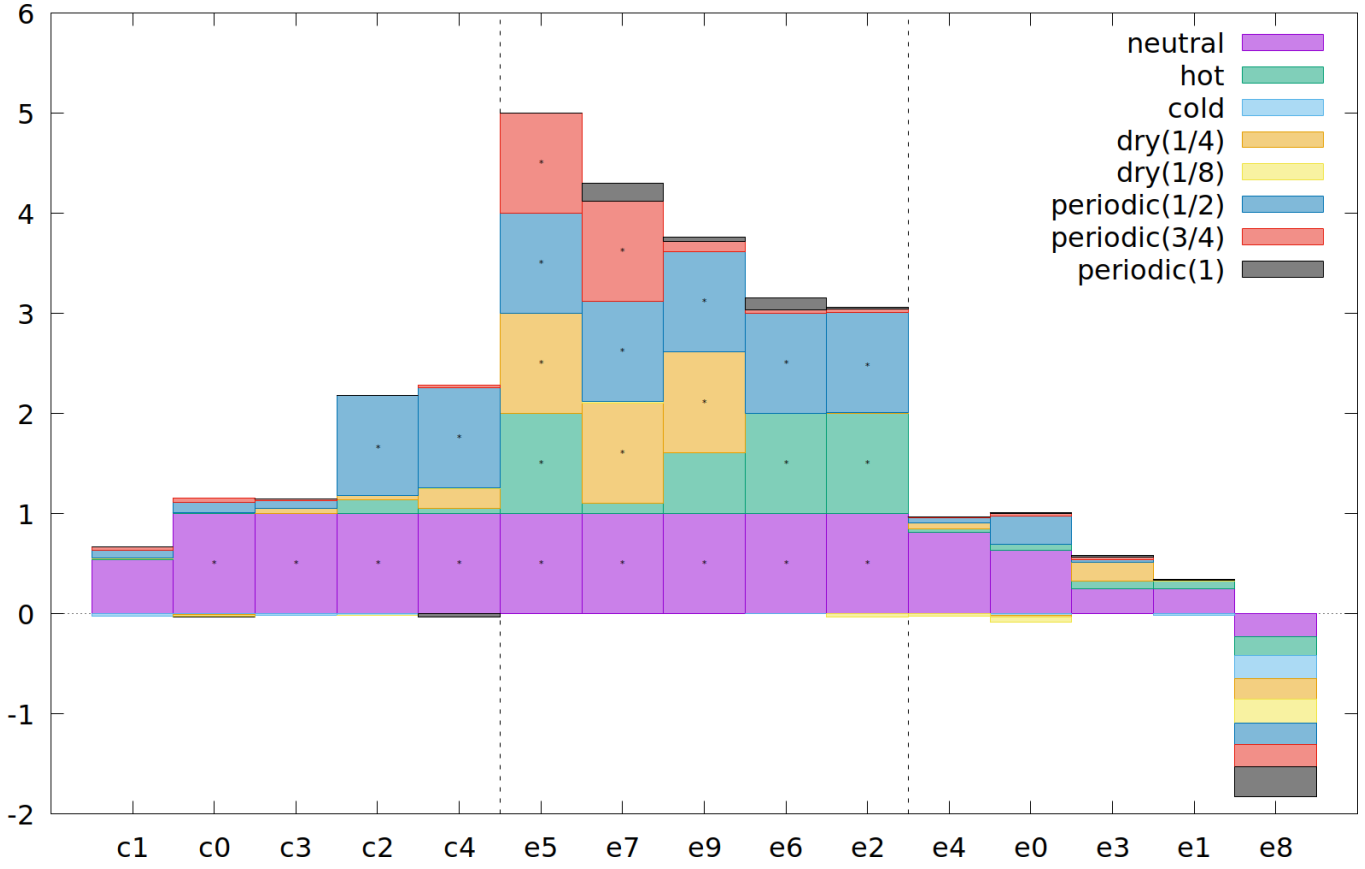
Promoting robustness

PvE



Promoting robustness

PvE

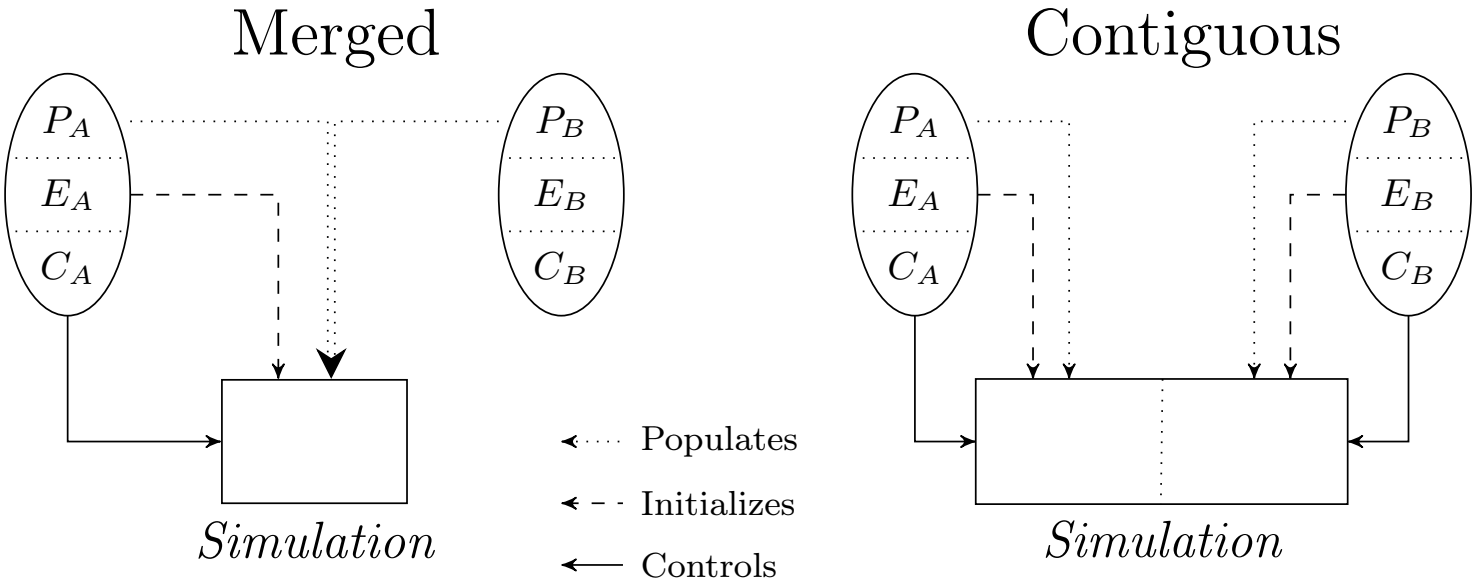


Evolved group (e) out-performs Control[1]

[1] Mann-Whitney, p-value < 0.05, outlier e_8 not considered

Promoting robustness

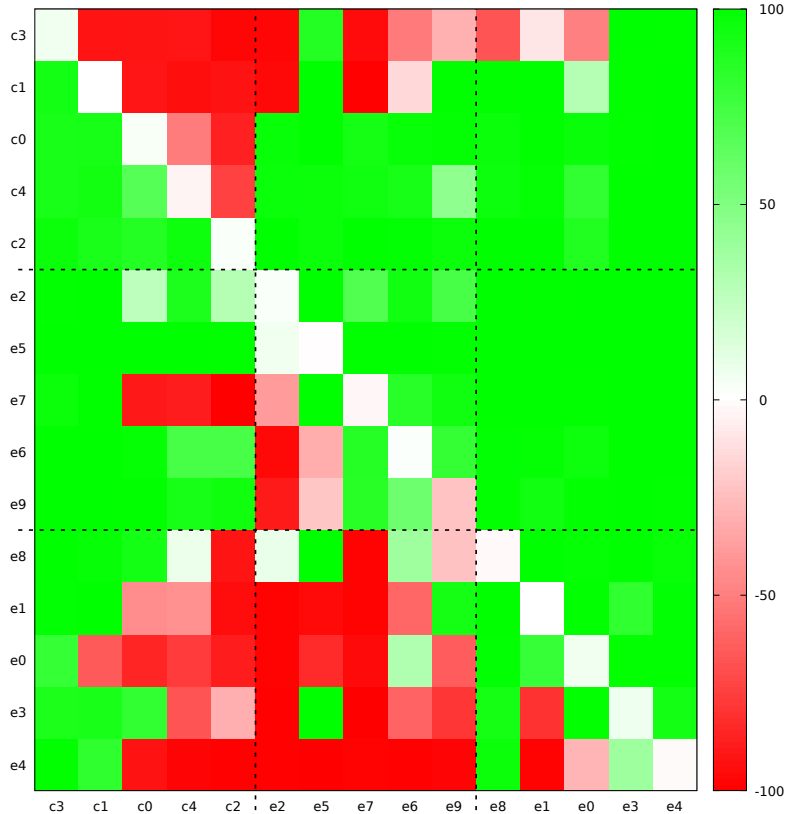
PvP



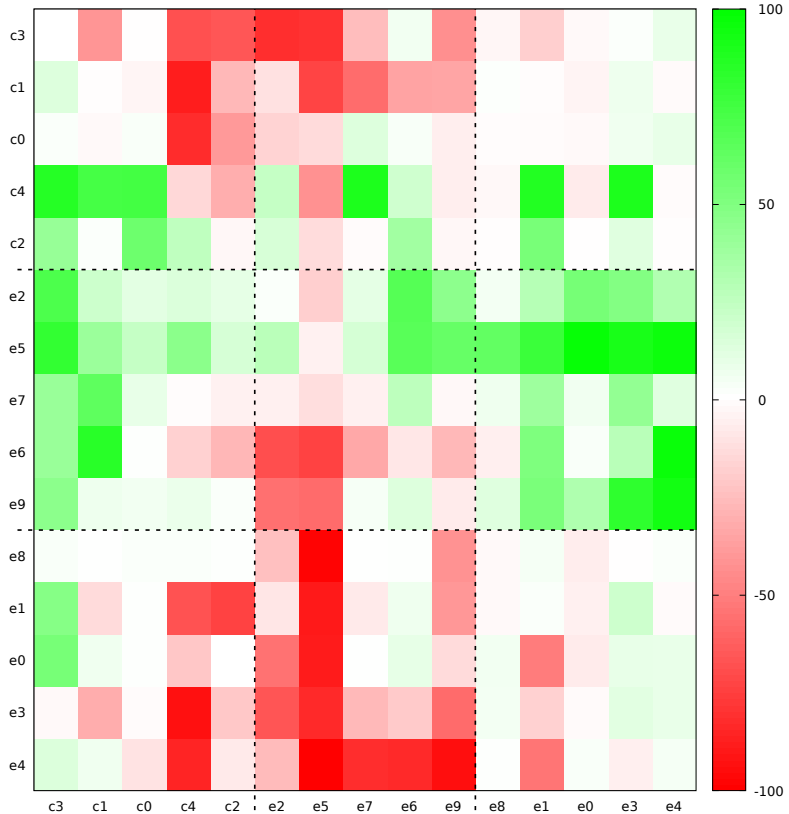
Promoting robustness

PvP

Merged

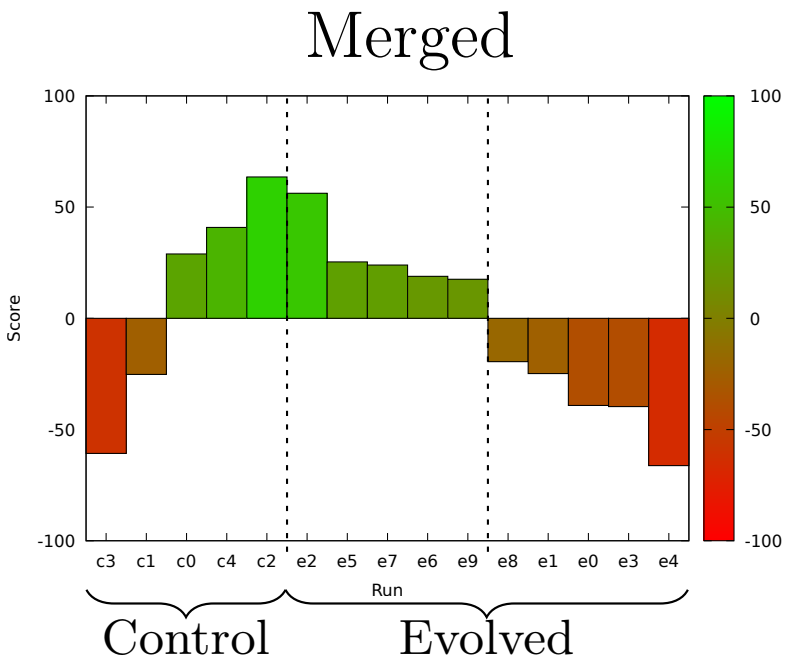


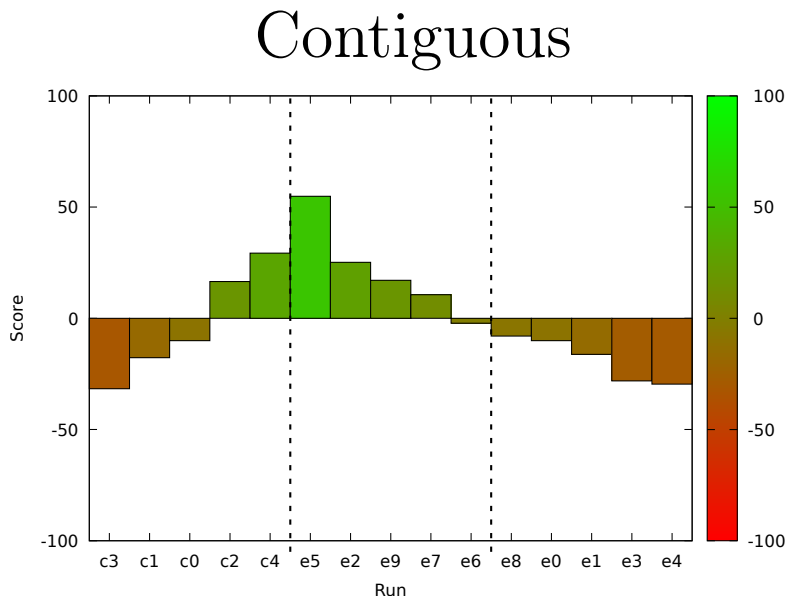
Contiguous



Promoting robustness

PvP

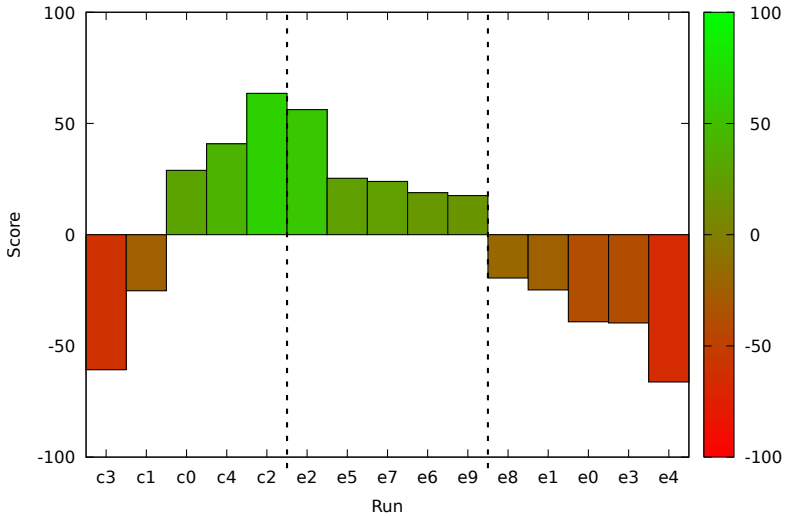




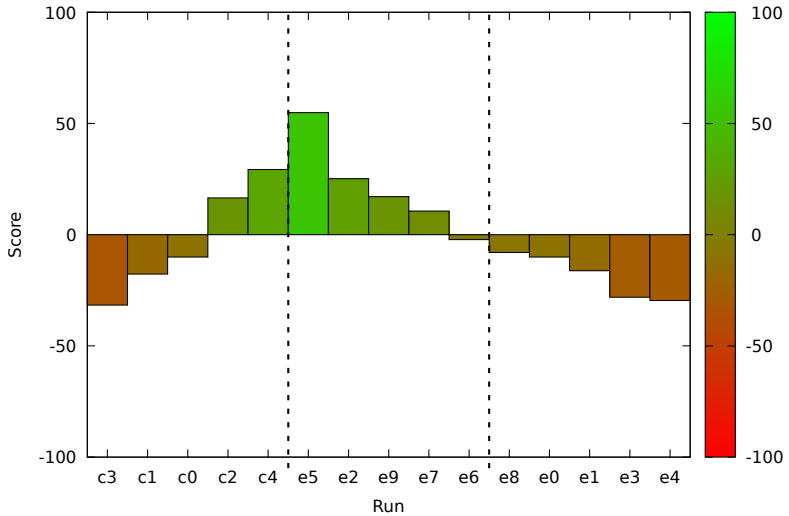
Promoting robustness

PvP

Merged



Contiguous



Statistical differences[2]:

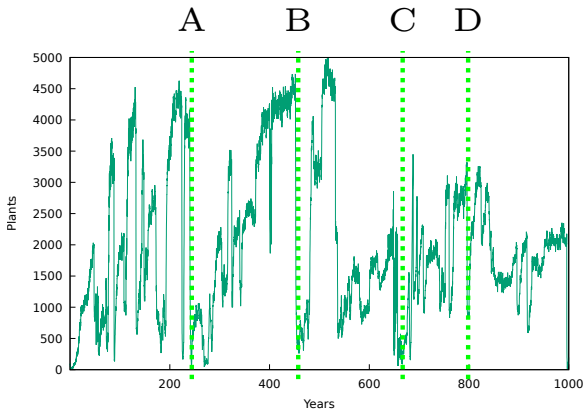
- Merged: e out-performed by c
- Contiguous: not significant

[2] Wilcoxon test, p-value < 0.05

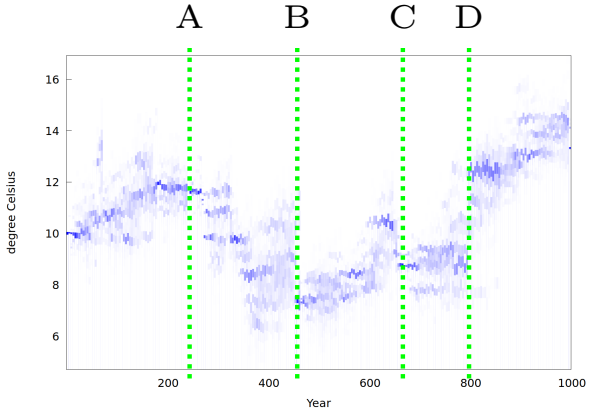
Insights

Individual strategies

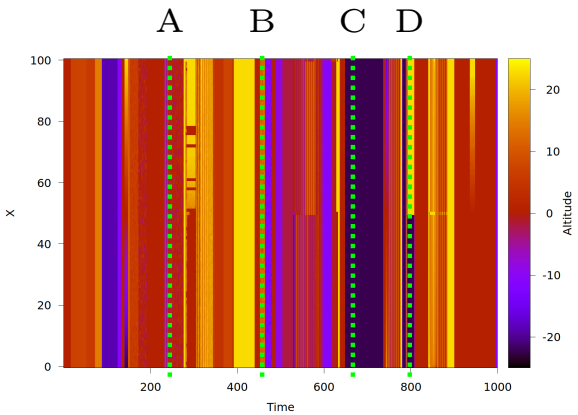
e_5: PvE and Contiguous PvP champion



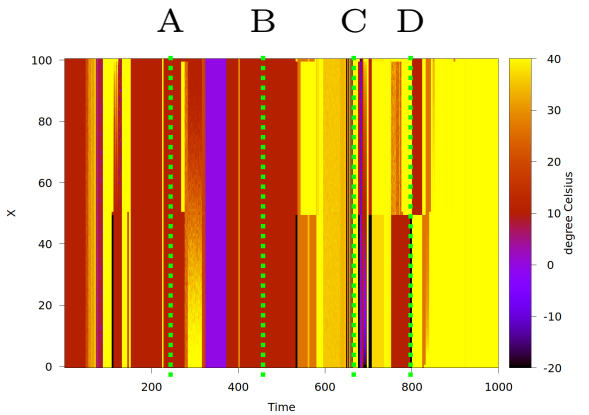
Variations of population size



Optimal temperature (gene)



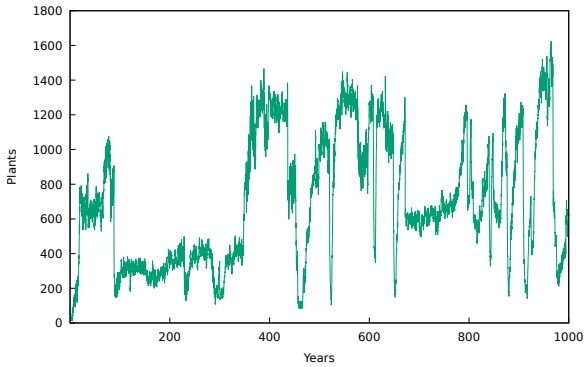
Environmental topography



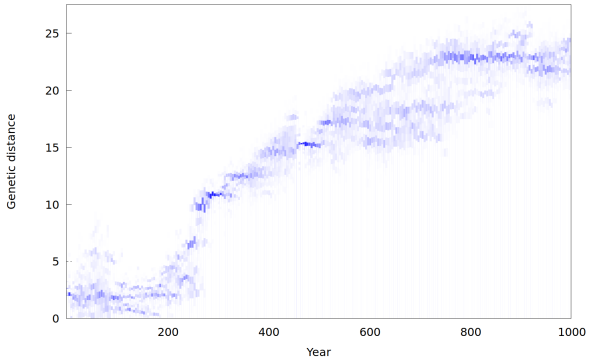
Environmental temperature

Individual strategies

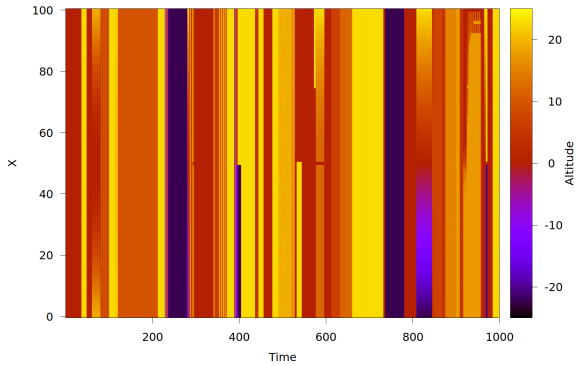
e_4: worst member of evolved group



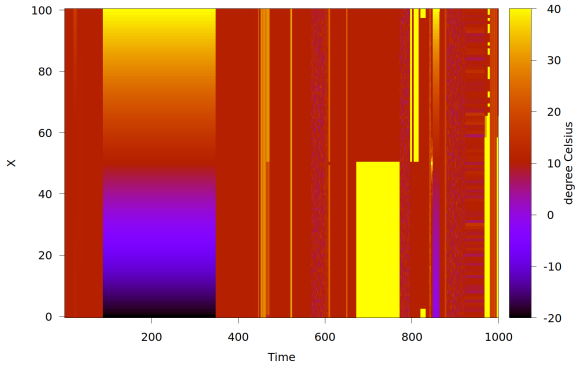
Variations of population size



Genetic distance (gene)



Environmental topography



Environmental temperature

Beneficial catastrophes

$$d_e = P_l(4(e-\nu)) - P_l(4(e+\nu)) \qquad P_r = \sum_{e=1}^{249} \frac{|d_e|}{249}$$

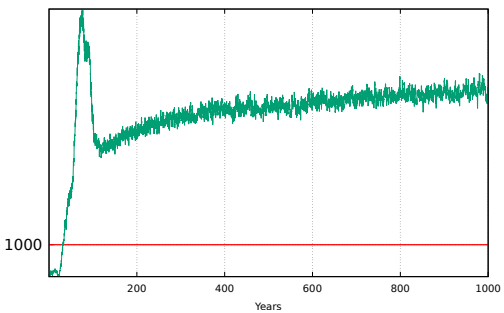
$$d_e^- = \begin{cases} d_e & \text{if } d_e < 0 \\ 0 & \text{otherwise} \end{cases} \qquad P_r^- = -\sum_{e=1}^{249} \frac{d_e^-}{249}$$

$$\bar{P}_r = \frac{P_r}{\bar{P}_l} \qquad \bar{P}_r^- = \frac{P_r^-}{\bar{P}_l}$$

with
- $P_l(t)$: Population size at time t
- e: Time in years
- ν: Integration window (0.25)
- $\bar{P}_l$: Average population size

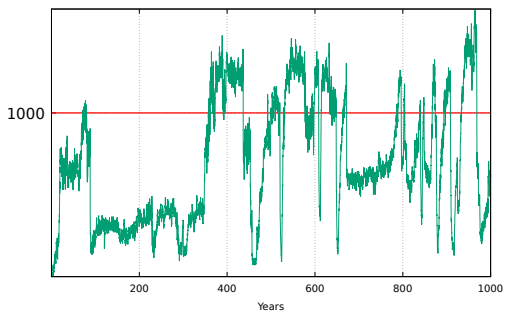
Beneficial catastrophes

c_0



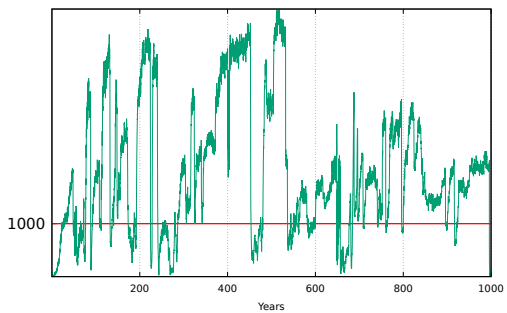
$\bar{P}_r = .02 \quad \bar{P}_r^- = .02$

e_4



$\bar{P}_r = .07 \quad \bar{P}_r^- = .08$

e_5



$\bar{P}_r = .11 \quad \bar{P}_r^- = .16$

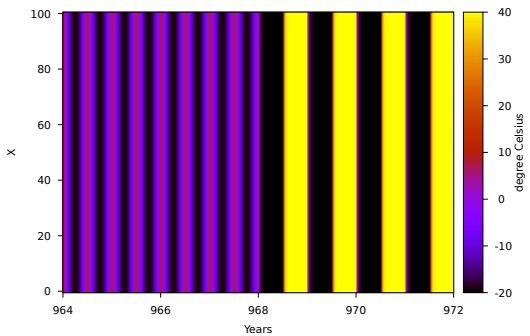
Beneficial catastrophes

Variable	c & e			e only		
	PvE	PvP		PvE	PvP	
		M	C		M	C
$\bar{P}_l$	.696	.589	.421	.697	.648	.697
P_r	.757	.625	.682	.685	.697	.733
P_r^-	.793	.589	.679	.770	.661	.733
$\bar{P}_r$	.564	.125	.511	**.891**	.758	.794
$\bar{P}_r^-$	.529	.193	.571	.782	**.927**	**.927**

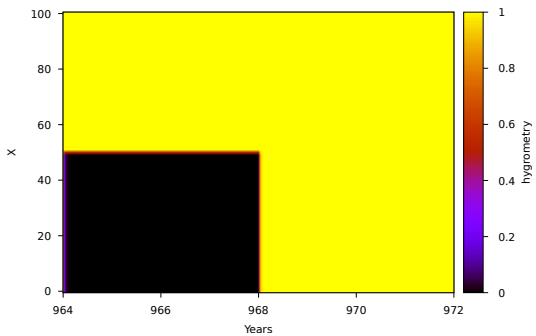
Positive correlations between scores and perturbation intensity[3]

[3] Spearman, grayed-out values are not significant under p-value < 0.05

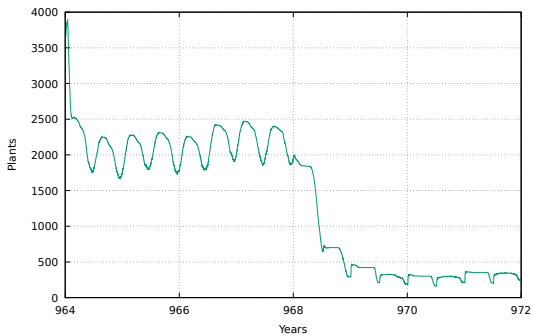
Resilience & Creativity



Temperature



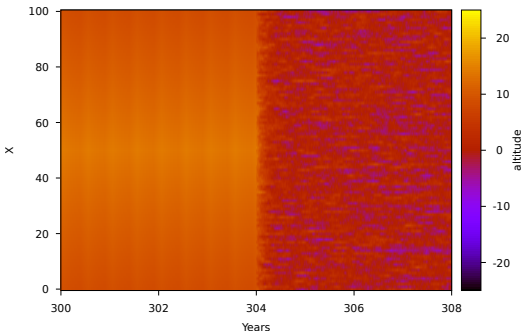
Hygrometry



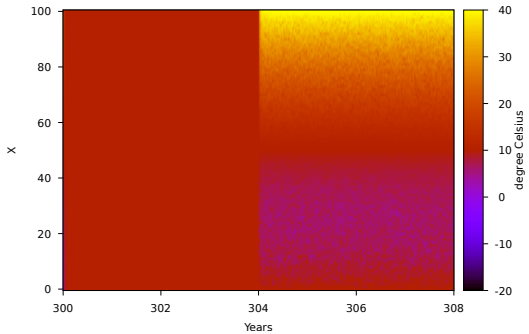
Population

Resilience & Creativity

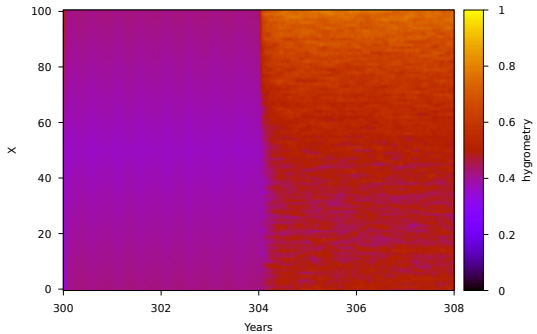
$T = \text{rand}$ $H(X) = X(\text{rand} < X)$ $W(T, H) = H - T$



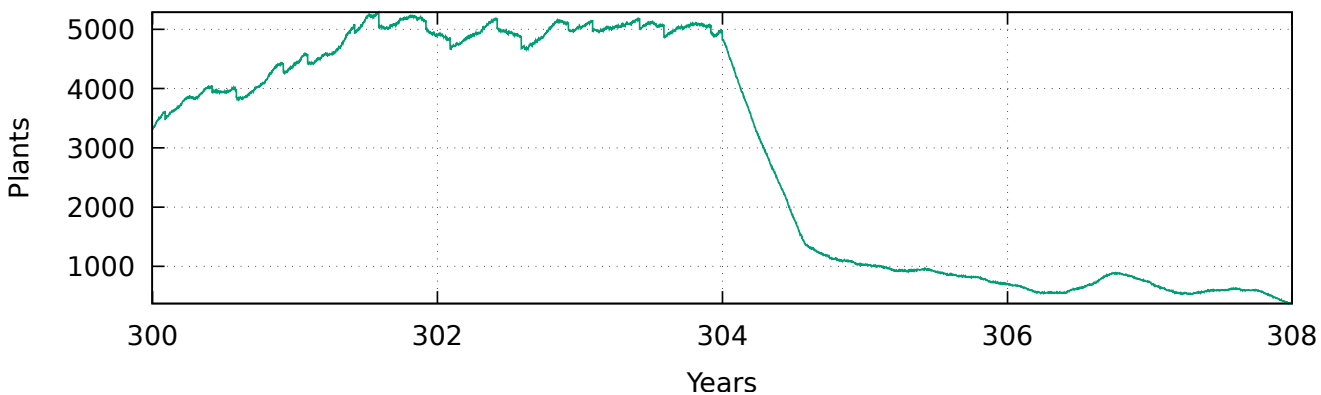
Topography



Temperature



Hygrometry



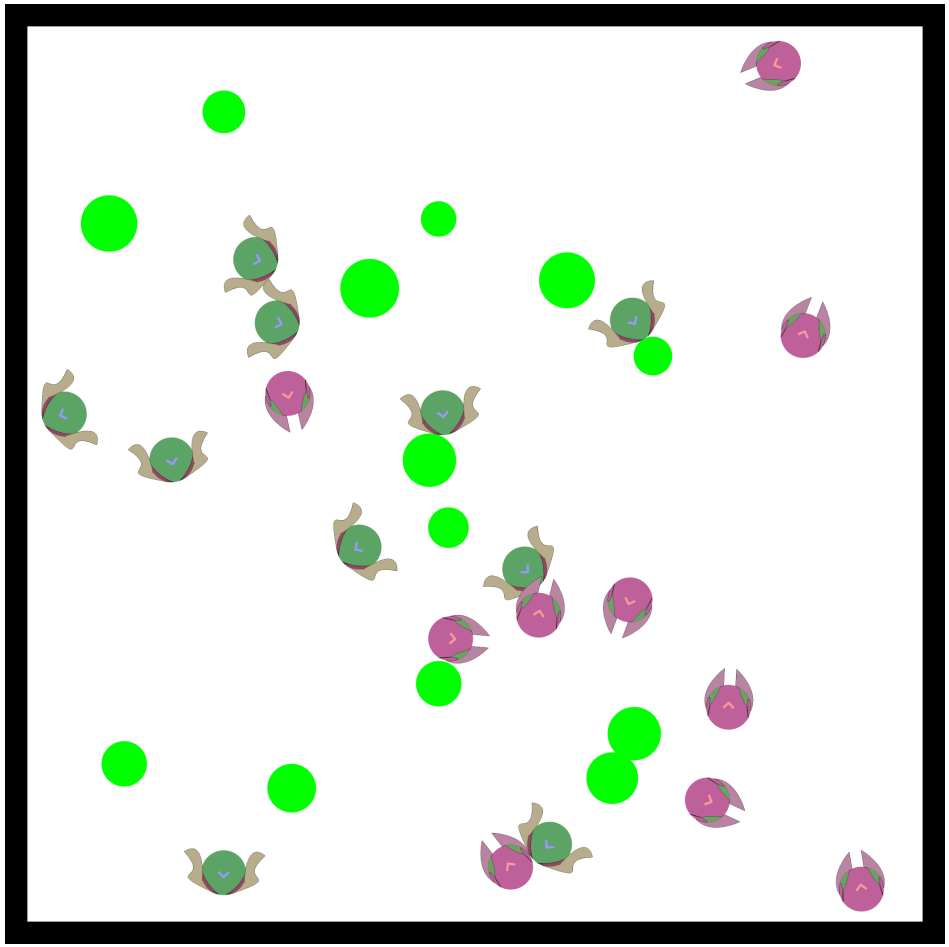
Population

Conclusion

Conclusion

- EDEnS: Environment-Driven Evolutionary Selection
- Application to abiotic robustness of virtual plants
- Showcased benefits of catastrophic trimming
- Generated out-of-the-box sets of constraints

Splinoids



Annexes

- References

References

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