Bayesian inference: learning and evolution

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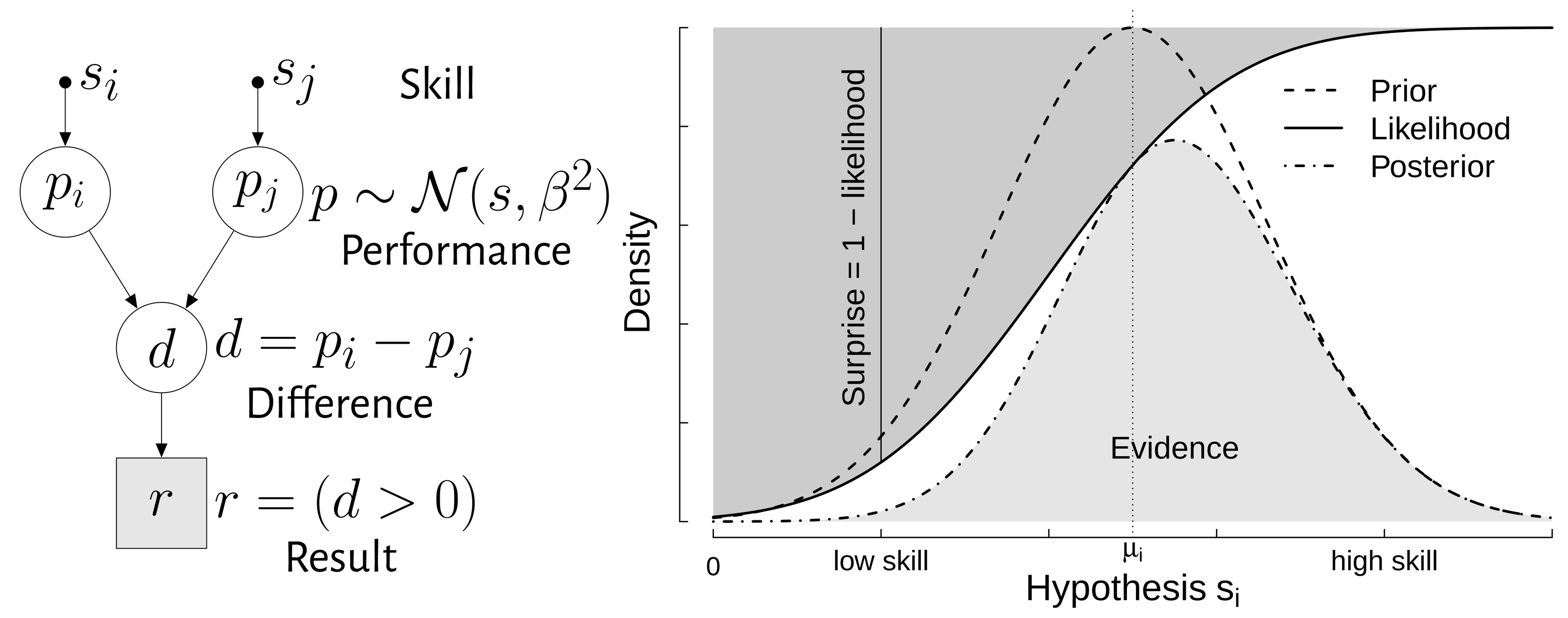
`github.com/glandfried/TrueSkillThroughTime`

TrueSkill Through Time (TTT)

Reliable initial skill estimates and historical comparability

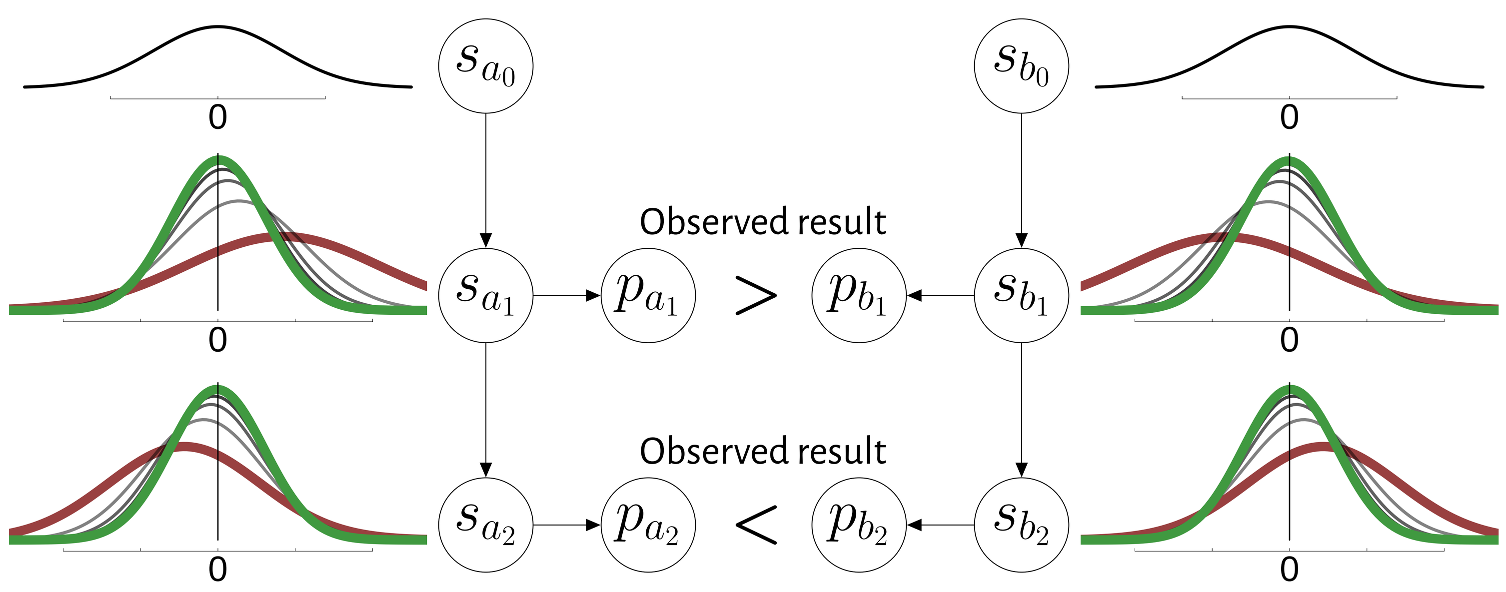
The TTT model is the current state-of-the-art skill estimator in the video game industry: it provides reliable initial skill estimates and guarantees historical comparability. Published more than a decade ago, it was not available in the programming languages with the largest scientific communities. In this paper we offer the first package for `Julia`, `Python` and `R`, an efficient algorithm that allows millions of observations to be analyzed using any low-end CPU.

Introduction. All skill estimators made pairwise comparisons.



(a) Model (b) A winner's posterior

Methods The TTT model propagates all historical information in a single Bayesian network providing better estimates,



To compare models we need to compute the bayes factor (BF),

$$\frac{P(\text{Model}_i|\text{Data})}{P(\text{Model}_j|\text{Data})} = \frac{P(\text{Data}|\text{Model}_i)\cancel{P(\text{Model}_i)}}{P(\text{Data}|\text{Model}_j)\cancel{P(\text{Model}_j)}}$$

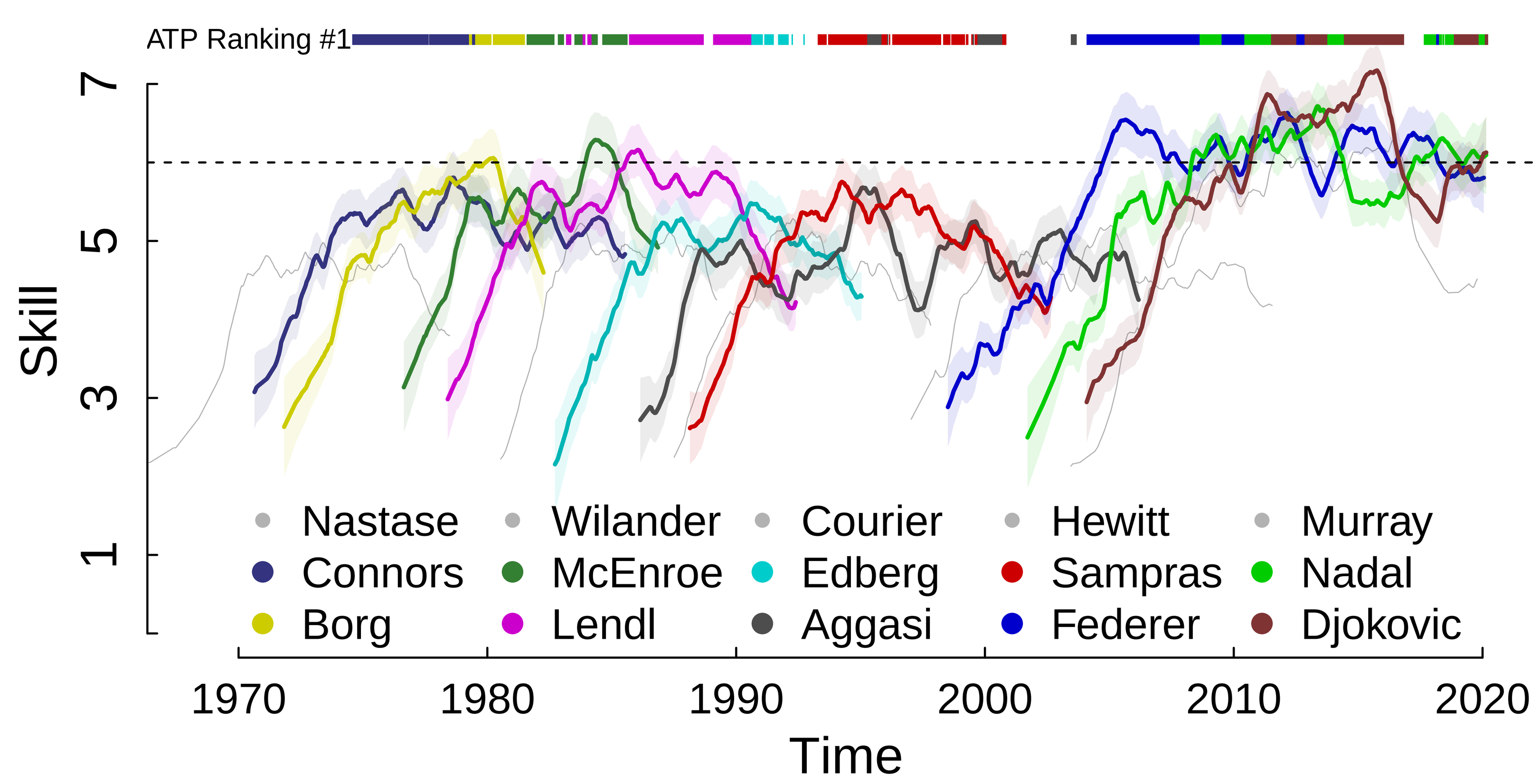
Therefor the geometric mean (GM) summarize the long-run growth rate that induces the probability of alternative models,

$$\begin{aligned} P(\text{Data}|\text{Model}) &= P(d_1|\text{Model})P(d_2|d_1,\text{Model})\dots \\ &= \text{geometric mean}(P(\text{Data}|\text{Model}))^{|\text{Data}|} \end{aligned}$$

Conclution The TTT model achieves better results than more complex models such as KickScore, in a more efficient way:

Dataset	Constant		Elo		TrueSkill		KickScore		TTT	
Test size	GM	$\log_2$BF	GM	$\log_2$BF	GM	$\log_2$BF	GM	$\log_2$BF	GM	LOOCV
ATP 186361	0.5593	7910	0.5695	3051	0.5722	1780	0.5758	93	**0.5760**	0.5908

This are the learning curves of historical ATP players.



`github.com/glandfried/transitions`

Evolutionary - Probabilistic isomorphism

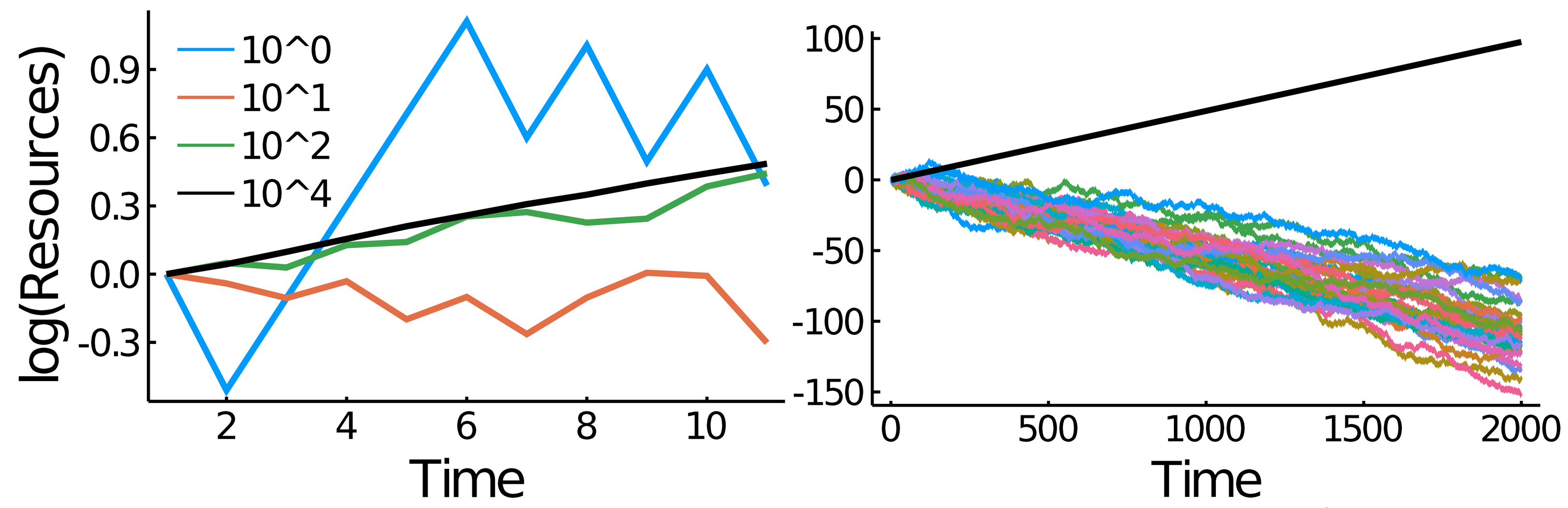
The irreversible emergence of cooperation and specialization

The current complexity of life is the consequence of a series of evolutionary transitions in which entities capable of self-replication after the transition become part of higher level cooperative units (eukaryotic cells, multicellular organisms, social systems). In this paper we show that the advantage in favor of cooperation and specialization is so common in the history of life because of the multiplicative nature of evolutionary and probabilistic selection processes.

Introduction In evolutionary theory a lineage growth is a multiplicative process: a sequence of survival and reproductive rates $f(\cdot)$

$$\omega(T) = \prod_t^T f(e_t) \approx r^T \quad \text{with} \quad f(e) = \begin{cases} 1.5 & e = \text{Head} \\ 0.6 & e = \text{Tail} \end{cases}$$

Which is the characteristic growth rate r?

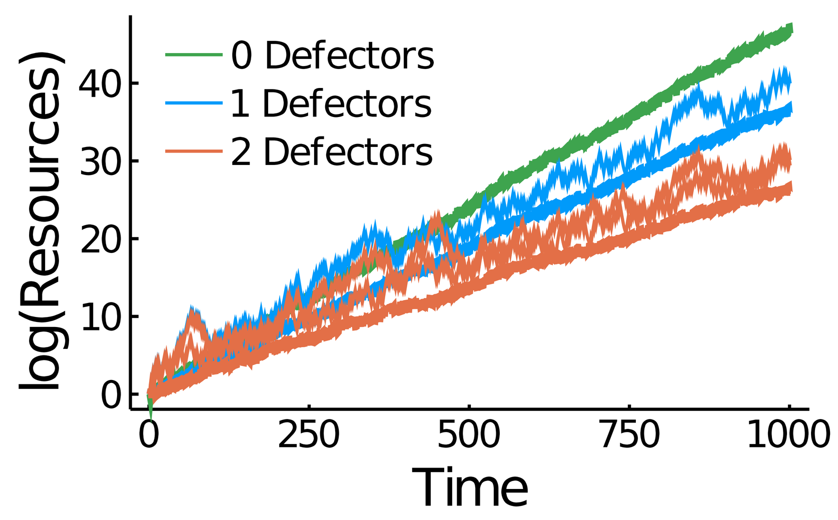


Arithmetic: $1.5 \cdot \frac{1}{2} + 0.6 \cdot \frac{1}{2} = 1.05$ Geometric: $(1.5 \cdot 0.6)^{1/2} \approx 0.95$

Generalizing $f(s,e) \propto s^e(1-s)^e$ with $s \in [0,1]$, the *replicator dynamic* equation states that the proportion of a strategy s is

$$P(s|\vec{e}^{1:T}) = \frac{P(s|\vec{e}^{1:T-1})f(s,e^T)}{\sum_s P(s|\vec{e}^{1:T-1})f(s,e^T)} \qquad \text{(Isomorphism)}$$

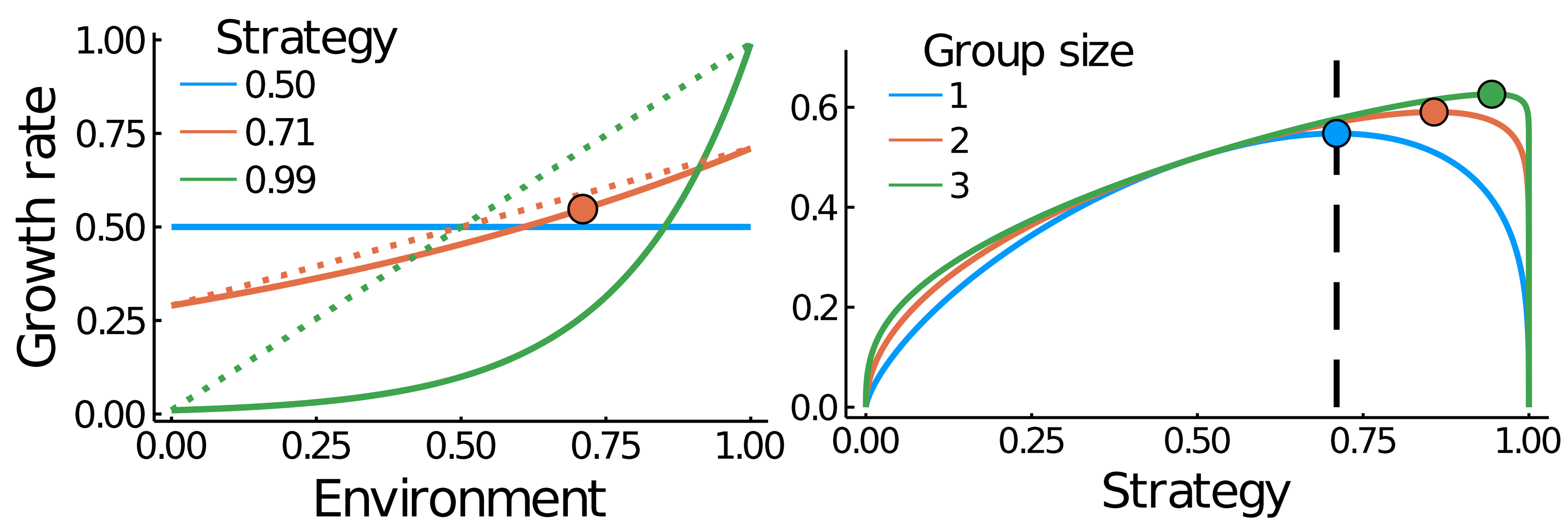
Results. Cooperation (pooling and sharing) benefits everyone. Defection increases fluctuations reducing even their own growth rate.



This is why multilevel selection favors cooperative individuals.

$$\underbrace{P(\text{coop}|\vec{e}^{1:T})}_{\text{Multilevel selection}} = \sum_g \underbrace{P(\text{coop}|\vec{e}^{1:T}, g)}_{\text{Individual selection}} \cdot \underbrace{P(g|\vec{e}^{1:T})}_{\text{Group selection}}$$

With cooperation, an advantage for specialist strategies appears



Since specialist strategies are individually poorly adapted to the environment, an irreversibility of the evolutionary transition is created.

Conclution. An advantage in favor of cooperation and specialization arises in our simple causal model because of the multiplicative nature of evolutionary and probabilistic selection processes.

Did you find the commonalities between the two papers?