The Dose Makes The Cooperation

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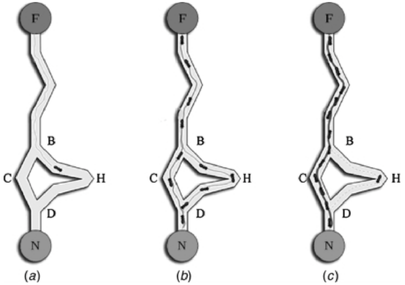
Outline



Ant Colony

Complex Systems

Whole is greater than the sum of the parts

- System can not be understood by looking its parts
- Non-linearity: Whole $\neq \sum$ parts

Complex Systems

Large number of interactions among simpler components (following simple rules), without a central control, give rise to hard-to-predict complex patterns of behavior.

More is different

H2O water molecules combined in a such a way that wetness emerges.

Model

A model is a simplified description of a system

> *Essentially, all models are wrong, but some are useful.*
>
> *Box, George E. P.*

Mathematical models work best for static equilibrating systems. To investigate richer more dynamic systems, we need computational models.

Agent Based Models

Agent

Autonomous component that can make independent decisions.

The Goal of ABM

- Search for explanatory insight
- Not to solve specific practical or engineering problems.

Object oriented programming

Objects are entities that have structure and state. State can be manipulated by operations.

How selfish beings manage to cooperate?

The construction of new features requires the cooperation of simpler parts

- replicating molecules $\rightarrow$ cells
- cells $\rightarrow$ organisms
- organisms $\rightarrow$ groups
- groups $\rightarrow$ societies, culture, civilisations

Darwin noted cooperation as a potential problem to his theory

Cooperative behavior involves a cost for the individual. It does not favor reproductive success.

Prisoner's Dilemma Game

Game

- Strategic interaction of self-interested agents.

PD game is described by

Payoff Matrix	Cooperate	Defect
Cooperate	R	S
Defect	T	P

where $T > R > P > S$.[1]

In order to maximize your payoff, which action will you choose?

[1] And $2R > T + S$ for repeated interactions.

Attention scarcity

The scarcest ressources of today is not information but rather attention.

Information Rich World

- We are exposed to increasingly abundant and immediately available information.

Attention Game

- Players can only pay attention to a portion of the information they recieve.

Genotype and Memory

Each agent is represented by its *genotype* and its *memory*.

- Memory is used for storing information.
- Genotype defines the characteristics of an agent.

Genotype is a 2-tuple $\langle p_d, \mu \rangle$.

- p_d : Probability of defection
  - Agent defects with prob. p_d and cooperates with prob. $(1 - p_d)$.
- μ: Memory size ratio
  - Memory determines the number of opponents one can remember. μ is memory size divided by population size.

Memory

Each memory slot is dedicated to one particular opponent. It stores two information:

- the numbers of defection received from the opponent
- the total number of plays with it.

Their ratio gives the perceieved defection rate of the opponent.

Assumptions & Interaction rules

Perception

- Defection rate threshold of 0.5

Norm of Reciprocity

- Agents are reciprocal and refuse to play with defectors.

Selective attention

When memory size exceeds, agents are required to decide which agents to keep in memory and which agents to forget.

- If memory size exceeds, primarily forget cooperators to keep attention on defectors.

Algorithm for Interaction

while *i confronts with a new opponent j* **do**
    if $j \in m(i)$ **then**
        if $\theta_j < 0.5$ **then**
            play with j;
            update θ_j;
        end
    else
        play with j;
        forget primarily cooperators;
    end
end

Reciprocation and attention are expected to foster cooperation.

Evolutionary Dynamics

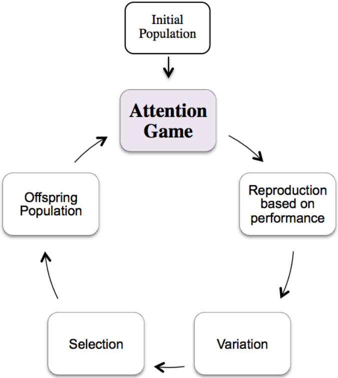
The average defection rate and the average memory size ratio of the current population is given by

- $\overline{p_d} = \frac{1}{N} \sum_{i=1}^{N} {p_d}^i$
- $\overline{\mu} = \frac{1}{N} \sum_{i=1}^{N} \mu^i$

Analysing the values of $(\overline{\rho}, \overline{\mu})$ pairs from generation to generation, will make us to see the co-evolution of cooperation and memory.

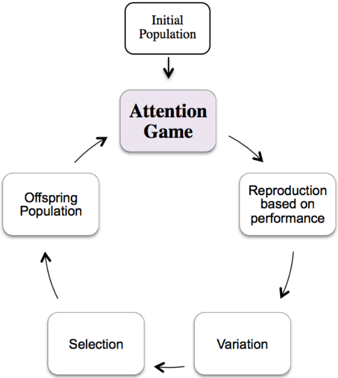
Evolutionary Dynamics

- Gene values, $\langle p_d, \mu \rangle$, are assigned randomly to the $N = 100$ individuals of the initial population.
- Members of parent population play attention game repeatedly.
- Population size, $N = 100$ is held constant. Lifetime of a generation, is fixed to the $\tau \times \binom{N}{2}$ where $\tau = 30$.



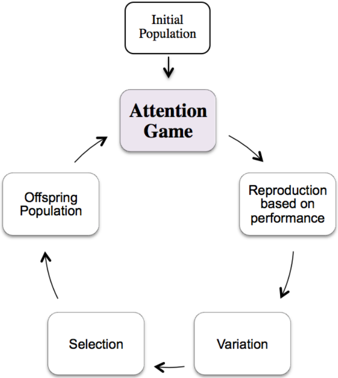
Evolutionary Dynamics

- Genes, $\langle p_d, \mu \rangle$, are in direct competition for taking their place on the chromosomes of the future generations.
- Agents with fitter genetic code, will gather higher payoffs. Agents who get higher payoffs have higher chance to reproduce.
- Each newborn agent genetically inherits the genotype of their parents.



Evolutionary Dynamics

- Evolution is about replication of information with tiny gradual changes.
- We used a mutation rate of 0.05, for variation. That is 5 % of the offspring population, will be different from their parents in one random gene only.
- Memory content of a newborn is initially empty.
- We have investigated 500 subsequent generations.



Simulations

In the first set of simulations, Memory size ratio, μ, is fixed for all agents of the population. $p_d \sim \mathcal{N}(0.5, 0.5)$. We use the standard payoff matrix with outcomes $T = 5$, $R = 3$, $P = 1$, $S = 0$.

	C	D
C	3	0
D	5	1

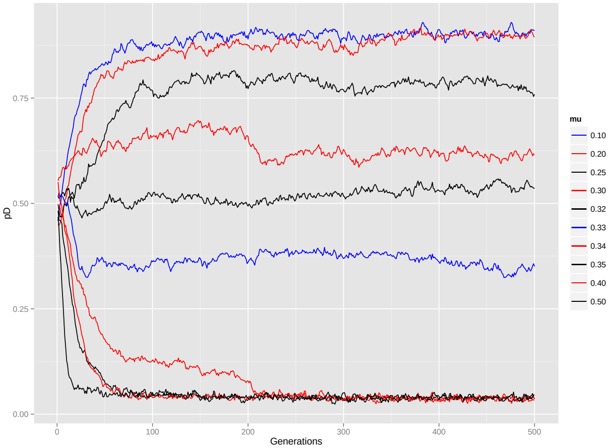


Figure: There exists a critical threshold for fixed μ in the range $[0.25, 0.35]$, above which cooperation emerges and below which defection emerges.

Co-Evolution of Cooperation and Memory Size

We want to relaxe the fixed memory size assumption. We will let our model to incorporate individual differences in memory size.

Initial population

In order to start with a highly protected population

- $p_d \sim \mathcal{N}(0.5, 0.5)$
- $\mu \sim \mathcal{N}(0.85, 0.1)$.

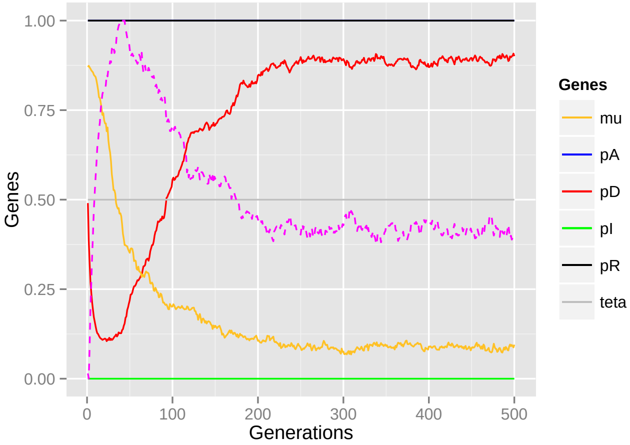


Figure: Unexpected path to the decrease of Memory Size.

From Consciousness Explained, by Daniel Dennett, p.177 "The juvenile sea squirt wanders through the sea searching for a suitable rock or hunk of coral to cling to and make its home for life. For this task, it has a rudimentary nervous system. When it finds its spot and takes root, it doesn't need its brain anymore, so it eats it! (It's rather like getting tenure.)"

The humble sea squirt has only one problem in life, to find a home. With no problems to solve, there's no need to waste energy on a brain

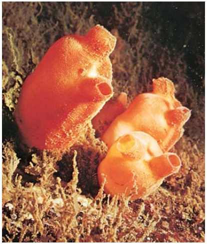


Figure: Sea Squirt

- Sea squirts simplify their brains during their lifetimes
- According to Frank Hirth, in their ancient evolutionary past, sea sponges did have neurons.

Figure: Sea Sponges

Why would an animal lose its brain?

Some extremely simple animals may have got rid of their brains because they simply had no need for one. And this could have been key to their success.

Co-Evolution Under Aggressive Defection

What would happen if the environmental conditions heavier for cooperators? Let's investigate the effect of a biased payoff matrix, where the sucker payoff is lower. This case can be considered as a more dangerous environment for cooperators.

We investigate the effect of a biased payoff matrix with outcomes $T = 5$, $R = 3$, $P = 1$, $S = -3$.

	C	D
C	3	-3
D	5	1

Figure: Cooperators learn to amplify their memory size, when environment gets more dangerous ($S = -3$).

Lets investigate the effect of a biased payoff matrix with outcomes $T = 5$, $R = 3$, $P = 1$, $S = -5$.

	C	D
C	3	-5
D	5	1

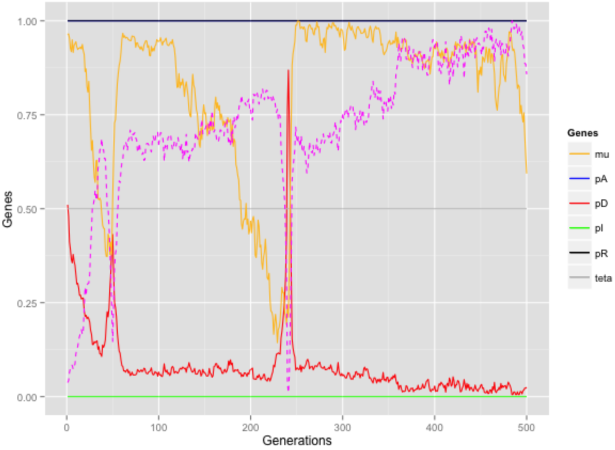


Figure: Cooperators learn to amplify their memory size, when environment gets more dangerous ($S = -5$).

Harmless Defection → Dumb Population

cooperators are the prey.

Aggresive Defection → Adaptive Population

defectors are the prey.

Figure: Lao Proverb: “When the water rises, the fish eat the ants; when the water falls, the ants eat the fish.”

Emergence of Self-Protection

Increasing memory size as an immunity response

- There exists not a single line of code in their programs that says increase the memory size, when confronted by more threatening defectors.

Emergence

Un-programmed functionality, that would probably upset software engineers, has emerged via the creative power of evolution.

Immune Systems

Self-Protection

- Living organisms must protect themselves from the attempt of other organisms to exploit thier resources.
- The **countermeasures** taken against the **would-be-exploiter**, constitutues the immune system of the host.

Memory Requirement

Antigenic recognition is the first prerequiste in order to mount an immunity response.

- self (cooperator)
- non-self (defector)

Evolution is continuing within you

Adaptive Immune System

- Negative Selection
  - Cells that are **not** self-tolerant are eliminated.
- Clonal Selection
  - Cells that are reactive against "nonself" are proliferated.
  - They undergo a hyper mutation process and those with higher affinity are selected.

A renewed viewpoint

Immune System

- Self-Nonself Model
  - Presence of “nonself” triggers immune response
- Infectious-Nonself Model
  - Presence of “widespread nonself” triggers immune response
- Tha Danger Model
  - Presence of “danger signals” triggers immune response

Immune system needs to adopt to a changing self and does not always react on foreign cells.

A renewed viewpoint

Negative Selection

- When everyone is cooperator (self), agents with higher memory size, self-reacts
- Self-reactive agents are eliminated, that is why memory collapes

A renewed viewpoint

In the absence of danger, cooperators loose their memory and eventually outcompeted by defectors.

- Natural selection chooses defection.

In the presence of danger, only cooperators with greater memory size can survive and proliferate.

- Natural selection chooses cooperation.

Clonal Selection

- Defection with damage, triggers an immunity response of having a greater memory size.

Conclusion

A first computational explanation for the Danger Theory

- Memory is a protection shield for cooperators, activated only facing with dangerous defection
- Danger constitues the imperative need for cooperators to adapt a greater memory size as an immune response against the defectos.
- Our findings may be considered as a first step to offer a computational explanation for The Danger Theory of immunology.

The End

Thank You

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