

# Natural Computation and Behavioral Robotics

Competition, Games  
and Evolution

# Overview

- What is Natural Gaming ?
- Zero sum and Non-zero sum Games
- Competitive and Cooperative behavior
- Evolution and Stable Strategies
- An example: “Tit-for-Tat” (T4T) strategy
- Properties of “good” cooperative strategies

# Natural Gaming

“Game”: Any situation where 2 or more adversaries try to get most while others do the same.

In Nature: compete against others for better access to (limited) food, territory, mates, etc.

Most common dilemma: “fight” or “flee” situation.

“Best” strategy is not always best because the opponent may also use it at the same time!

“They look at you in the best hiding places first...”

# Zero Sum Games

- Example: “Hawks vs. Doves” (John M. Smith)
  - Hawk: aggressive behavior, “fight” rather than “flee”
  - Dove: defensive behavior, “flee” rather than “fight”

- Neither pure “Hawk” or pure “Dove” strategies are all-win situations

(R→C)	Hawk	Dove
Hawk	0	3
Dove	1	2

- Solution: some choose one and some the other
- “How many?”  $\Rightarrow$  Depends on the matrix values!

# Non-Zero Sum Games

- Example: “Chicken”
  - Swerve: defensive behavior, “chicken” to avoid collision
  - Drive: aggressive behavior, “persist” and win the race

- Neither pure “Swerve” or pure “Drive” strategies are all-win situations

(A↔B)	Swerve	Drive
Swerve	(3,3) <sup>^</sup>	(2,4) <sup>*</sup>
Drive	(4,2) <sup>*</sup>	(1,1)

- Solution: choose safely or “bluff” your opponent
- “How many?” ⇒ Depends on the matrix values!

Famous “Chicken” game: Cuban Missile Crisis (1962)

## A special case – Prisoner's Dilemma

- “Prisoner's Dilemma” situation
  - Mute: cooperative behavior, “no-talk” in the interrogation
  - Spike: competitive behavior, “talk” in the interrogation

- “Spike” seems better, but cooperation for mutual “no-talk” is the optimum

(A↔B)	Mute	Spike
Mute	(3,3)	(1,4)
Spike	(4,1)	(2,2) <sup>^*</sup>

- Solution: best result for **both** if they communicate
- Demonstrates difference between “personal” and “collective” gain

Famous “P.D.” situation: Post-Cold War deterrence strategy for WMD.

# Competitive Behavior

- Players “fight” each other to gain an advantage
- “Fight” may resolve in double profits or severe consequences (energy, injuries, etc)
- This is usually the default behavior of a species when living alone or against another species
- Zero sum games: “fight” is the only option available
- Non-zero sum games: all players try to maximize their own gain, despite what their opponents do.

# Cooperative Behavior

- Players “agree” on a fair bargaining solution of split gains
- “Agreement” may reduce direct gain but also avoids severe losses (energy, injuries, death, etc)
- This is usually the default behavior of a members of the same species when living in groups or herds.
- Zero sum games: cooperation not applicable
- Non-zero sum games: players can “bargain” on a mutually beneficial solution, without any real “fight”.

# Evolution and Stable Strategies

- Evolution: a sequence of iterative steps of a process that changes and adapts a system to the current environment.
- Optimal Solutions: competition for limited resources ends up in some “stable” configuration that allocates them optimally.
- Stable Strategies: Behavioral patterns that eventually lead Evolution to Optimal solutions.
  
- **Optimality Criterion**: Natural selection drives the population to optimally exploit the available resources
- **Evolutionary Stable Strategies (E.S.S.)**: Behavioral patterns that “survive” during the process of Evolution.

# E.S.S. Example: “Tit-for-Tat” (T4T)

## Basic principle of T4T:

1. On the first iteration, take the most “defensive” or “kind” or “cooperative” action available.
  2. On each of the next iterations that follow, do what the opponent did on the immediately preceding step.
- Rule 1 makes sure there is a chance of **cooperation**
  - Rule 2 makes sure the opponent “learns” by **retaliation**
  - “Punishment” of the opponent is as important as the “kind” tactic on the very first step (beginning of the game).
  - T4T has proven very efficient in terms of **emergence of cooperation and adaptiveness** to changing environments.

## Properties of “good” E.S.S.

- Robustness: surviving against any other strategy, more or less “intelligent” than own.
- Stability: once established, preserved
- Initiation: (cooperation) survive even when all other players are “hostile”, i.e. non-cooperative.
- **In Practice**: a “good” cooperative E.S.S. should be “**Nice**”, “**Retaliatory**”, “**Forgiving**” and “**Optimistic**”.
- Cooperative E.S.S. are the key to **flocks** and **herds**.

# Food for thought

- How “kind” can a player be before getting eliminated by hostile opponents ?
- Why retaliation in T4T has to come immediately in the very next play ?
- Can T4T strategy beat an advanced AI program in a computer game like chess ?
- How does T4T strategy perform in the iterative form of the classic “Chicken” and “Prisoner’s Dilemma” ?

## P.C. – Readings

- John L. Casti, “Reality Rules II: Picturing the World in Mathematics – The Frontier”, John Wiley & Sons, 1997. [see: ch.5]
- Tom Mitchell, “Machine Learning”, McGrawHill, 1997. [see: ch.9, ch.13]