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	-3 (0)	+2 (3)
Dove	<u>-1</u> (1)	+1 (2)

- <u>Solution</u>: **Minimax** theorem (if zero-sum game)
- “How many?” ⇒ 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)	**(2*,4*)**
Drive	**(4*,2*)**	(1,1)

- Solution: Nash equilibrium (and generalizations)
- "How many?" ⇒ Depends on the matrix values!

Famous "Chicken" game: Cuban Missile Crisis (1962)

A special case – Prisoner's Dilemma

- "Prisoner's Dilemma" situation
  - **Silent**: cooperative behavior, "no talk" in the interrogation
  - **Confess**: competitive behavior, "talk" in the interrogation

- "Confess" seems better, but cooperation for mutual "Silent" is the optimum, when played *iteratively*

(A↔B)	Silent	Confess
Silent	(3,3)	(1,4*)
Confess	(4*,1)	**(2*,2*)**

- Solution: best result for **both** if they "cooperate" (Silent)
- Demonstrates difference between "personal" and "collective" gain

Famous "P.D." situation: Post-Cold War deterrence strategy for WMD (arsenal scale-down).

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: not applicable here, all players try to maximize their *own* individual gain.

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, maybe without "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 (A. Rapoport, R. Axelrod – 1980):

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 in changing environments.

Properties of "good" E.S.S.

- <u>Robustness</u>: surviving against any other strategy, more or less "intelligent" than own.
- <u>Stability</u>: once established, preserved
- <u>Initiation</u>: (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]