A bit about Evolutionary Game Theory (EGT)

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What's game theory?

- You may heard of game theory from *A Beautiful Mind (2001)*
- Maybe Nash equilibrium or The Prisoner's Dilemma
- But what does the notion of 'game' imply empirically? Simply put, game theory provides us the tools to investigate how rational agents (you or me) would want to interact in a scenario where a 'reward' is involved.

Introductory notation

- We have set of players $N = \{1, ..., n\}$, for this presentation we're focusing on two player games.
- Each player i chooses an action $a_i \in A_i$ depending on past actions etc.
- Each player has a respective utility function representing the 'reward' they get from the chosen move $u_i : A- > \mathbb{R}$

Some examples of common games

- The two main examples of games are the Prisoner's Dilemma and the hawk-dove game (predator-prey).
- Each of the matrices below represents what's called a payoff-matrix. V being anticipated value and h the cost of interacting for our hawk-dove game.

Sam's Actions \ John's Actions	Stay Silent	Betray
Stay Silent	(-1 , -1)	(-3 , 0)
Betray	(0 , -3)	(-2 , -2)

$u_{Sam}(Betray, Silent)$ $u_{John}(Betray, Silent)$

s_{Sam} s_{John}

A \ B	Hawk	Dove
Hawk	$\left(\frac{V}{2}-h, \frac{V}{2}-h\right)$	$(V, 0)$
Dove	$(0, V)$	$\left(\frac{V}{2}, \frac{V}{2}\right)$

Biological contexts

- Biologists find game theory useful in describing many natural world occurrences. It can be especially useful in approximating long-term populations.
- An agent can interact in numerous ways with other agents. Each of these interaction strategies can vary depending on resulting payoffs.
- After many iterations of games, an agent would end up with a 'preferred' evolutionary stable strategy. This strategy aims to maximise the agents payoff and survival long-term.

What are the types of interactions

- In simple contexts, you can have cooperation and combative interactions. These would 'passive' and 'aggressive' if you look at it in predator-prey terms.
- For our hawk-dove game, the hawk would end up 'winning' as it consumes doves even though the dove-dove strategy may have a higher value overall.
- A cooperation strategy however can be beneficial for the prisoner's dilemma game. It turns out the best move is if both prisoners stay quiet (**no snitching!**).

Evolutionary Stable Strategies (ESS)

- An Evolutionary Stable Strategy (ESS) is the strategy that ends up 'dominating' long term.
- An ESS would have to satisfy these two conditions
  - An individual employing strategy A must do better or the same against another individual employing strategy A.
  - Should a new strategy evolve (A') that does equally well against strategy A, for A to be an ESS, an individual employing strategy A must do better against an individual employing strategy A' than an individual employing strategy A'.

Further observations

- An ESS strategy is 'pure' if it ends up as the dominant strategy and the agent doesn't diverge from that strategy.
- A strategy is no longer ESS for mixed games where strategies can vary depending on relative population counts.
- This is especially interesting since we see unconventional strategies dominate like 'tit-for-tat' or cooperation for minimising mutual harm. You can also have pure 'altruism' as a strategy (EA anyone?)
- We can use these tools to investigate sociological instances whether it's MAD policy or some other complex group oriented interactions.

Questions?

Acknowledgements

- Material of the talk was referenced from Charles C. Cowden's *Game Theory, Evolutionary Stable Strategies and the Evolution of Biological Interactions*
- CSC2556 Algorithms for Collective Decision Making slides from Nisarg Shah here

Playing a game is the voluntary attempt to overcome unnecessary obstacles

— Bernard Suits (2005)