Algorithmic Game Theory Semester Project

Topic - Hawk and Dove

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Evolutionary Game Theory

- Evolutionary ecologists aim to understand the complex behavioral relationships between organisms as they interact to obtain resources.
- In general, these interactions range from antagonistic to cooperative, but cases of exploitation and altruism also occur.
- Interactions are costly: energy is invested by each organism in both confrontation and cooperation to acquire the resource. Even avoidance can be costly if energy is expended, and no resources are obtained.
- The energy spent is a cost to the organism, and the resources are benefits. Comparing the relative cost to the benefits obtained following an interaction determines the net gain or loss incurred by the organism, and this value is referred to as the payoff.
- Different interaction strategies, such as combative or cooperative, result in different payoffs based on nature of the interaction.
- The most successful organisms maximize their payoff and increase their ability to reproduce. In short, the organism with the best interaction strategy has the highest fitness.
- In this project we shall see one such example, The Hawk and Dove Model.

Hawk-Dove Model

- The hawk-dove model is an evolutionary game theoretical model developed by John M. Smith (1982).
- The model describes the contest between two fundamentally different behavioral strategies, hawks (selfishness) and doves (Pro sociality), when competing over a shared resource.
- If natural selection is based on competition, then prosocial traits should not evolve. The hawk-dove model provides a simplistic framework to investigate the conditions that favors the evolution of prosocial behavior.
- Overall, a hawk outcompetes doves within groups, but a group of doves outcompete a group of hawks.
- Thus, for either species to evolve an Equilibrium shall exist, and we shall explore it.

Objective

- To verify the MSNE as evolutionary stable strategy.
- To explain the change in population distribution using the theoretically computed MSNE.

Hawk and Dove – Normal Game Form

- Game = < {1, 2}, {Dove, Hawk}, u>
- Players : Player 1 and Player 2
- Strategy :
  - Hawk – An aggressive Strategy, they fight for food.
  - Dove - A Defensive Strategy, they share the food.
- Utility Matrix : B – Available Food, C – Cost of fighting

Player 1 \ Player 2	**Hawk**	**Dove**
Hawk	B/2 - C, B/2 - C	B, 0
Dove	0, B	B/2 , B/2

Equilibriums in Hawk & Dove

- If B/2 - C > 0
  - Then Hawk, Hawk is a strictly dominant strategy equilibrium.
- Else when B/2 - C <= 0
  - If Player 1 chooses to Hawk and Player 2 chooses to play Dove (PSNE)
    - Then no player has an incentive to change their strategy, B > B/2 and 0>= B/2 - C.
  - If Player 1 chooses to play Dove and Player 2 chooses to play Hawk (PSNE)
    - Then no player has an incentive to change their strategy, 0>= B/2 - C and B > B/2 (PSNE)

Player 1 \ Player 2	Hawk	Dove
Hawk	B/2 - C, B/2 - C	B, 0
Dove	0, B	B/2 , B/2

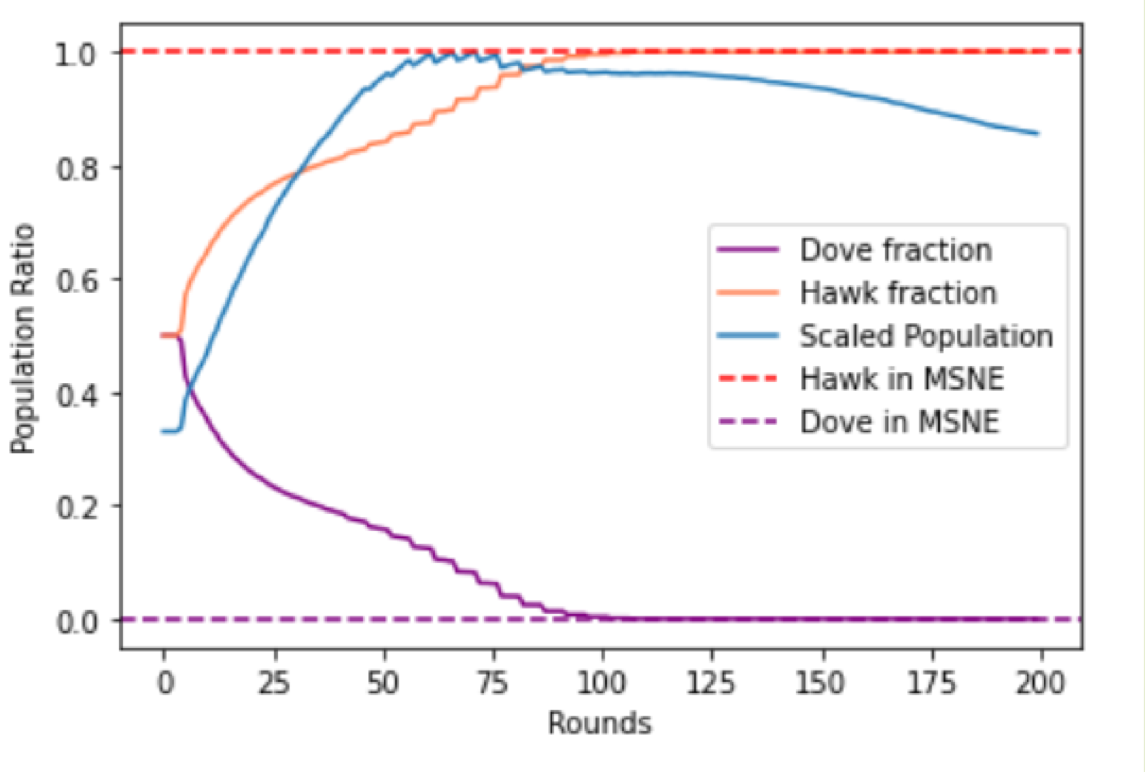
  - Else when player 1 chooses Hawk and player 2 chooses Hawk, then both players have an incentive to unilaterally change their strategy to Dove, since 0 >= B/2 - C.
  - Else when player 1 chooses Dove and player 2 chooses Dove, then both players have an incentive to unilaterally change their strategy to Hawk, since B >= B/2 .

MSNE in Hawk and Dove

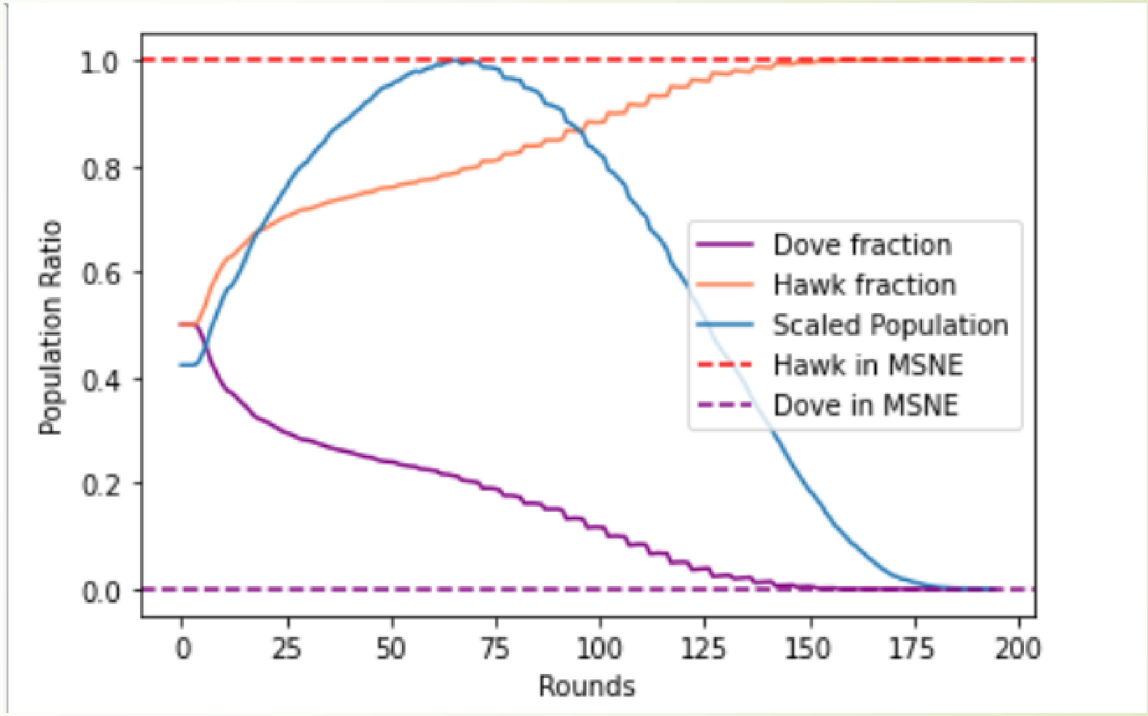
- When B/2 - C <= 0,
  - The game has a Mixed Strategy Nash Equilibrium
    - { {B/2C, 1 – B/2C}, {B/2C, 1 – B/2C} }
    - In other words, player plays hawk with B/2C probability and plays dove with 1 – B/2C probability.
    - This MSNE can be interpreted as the ratio of population having the traits Hawk and dove under equilibrium condition. And we shall verify this using a simulation.

Simulation vs Theory

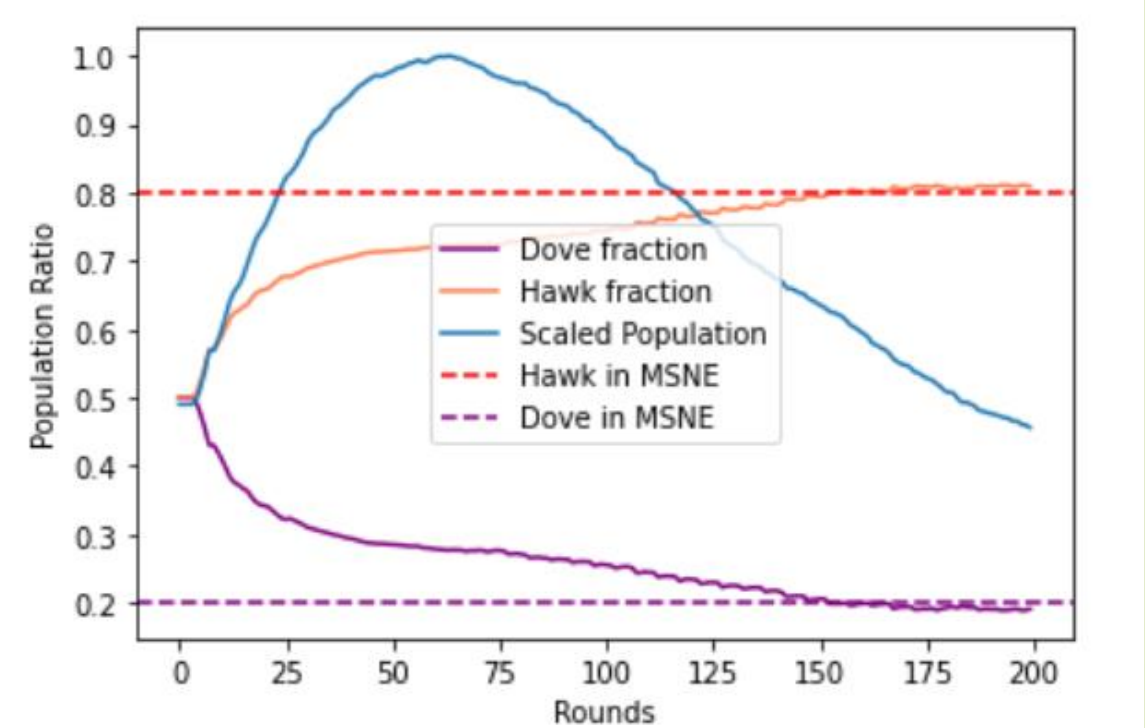
- Case of SDSE
- B = 40 and C = 10
- Hawks dominates Dove
- Since B/2 - C > 0



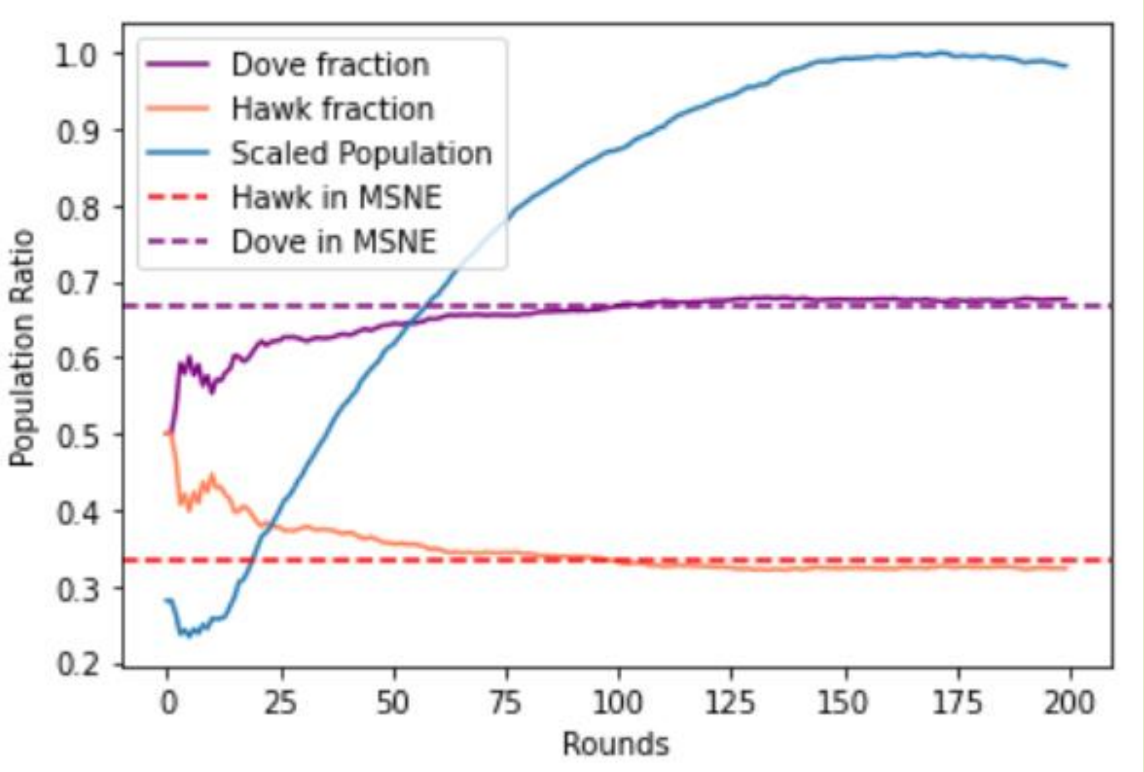
- SDSE
- B = 40, C = 20
- Still SDSE, but the population dies soon since B/2 = C, which implies utility = 0 for hawk vs hawk and thus they lose energy in subsequent rounds after attaining equilibrium the population dies.



- MSNE
- B = 40 and C = 25
- Hawk: Dove = (80 : 20)
- total Population 1861



- MSNE
- B = 40, C = 60
- Hawk : Dove = (33: 67)
- Population size: **6993**
- Population increase because doves share the resource while hawks fight over the resource.



Conclusion

- Our simulation verifies the MSNE as evolutionary stable strategy.
- When B-2C > 0, then the hawks dominated the population.
- And as we increased the value of C (i.e., cost of fighting) the dove population started to increase.
- And since doves share and don't waste energy on fighting (defensive strategy) the population size started to increase, and it went from 1861 to 6993 when we change C from 25 to 60.
- For an ideal community to increase its population they must punish the Hawk community by increasing cost of fighting.