Football IV

Produced by Dr. Mario | UNC STOR 390

Football Decision Making

- 5 Key Decisions in Football
  - Fourth and 4 on Opponent's 30 Yard Line. Field Goal or Punt?
  - Fourth and 4 on Own 30 Yard Line. Attempt or Punt?
  - Gained 7 Yards on First Down From Own 30 Yard Line and Defense Was Offsides. Accept the Penalty?
  - Opponent Gained 0 Yards on Run on First Down. They were Offside. Accept the Penalty?
  - Optimal Run/Pass Mixture on First Down?

- Decision Based on States of Football
- Best Decision Maximizes the Expected Number of Points

$$Expected\ Points = V(Down, Yards\ For\ 1st\ Down, Yard\ Line)$$

Football Decision Making

- Examples of Expected Points Based on States
  - $V(1,10,50) = 1.875$
  - $V(3,3,80) = 3.851$
  - $V(2,9,5) = -1.647$
- Works of Konstantinos Pelechrinis
  - Papers on Football Strategy and

Football States and Values

- Football States Defined by …
  - Yard Line
  - Down
  - Yards to Go for First Down
  - Score Differential
  - Time Left in Game

- There is a Massive Amount of States

$$Number\ of\ States = 99 \times 4 \times 30 \times 80 \times 60 = 57{,}024{,}000$$

Assumption About Yards to Go

Assumption Score Differential

Assumption About Time Remaining

Football States and Values

- Needs Simplification
  - Maximize the Expected Number of Points
  - Assume Game is of Infinite Length
  - Time Remaining Becomes Irrelevant
  - Current Score Differential Becomes Irrelevant
  - Method Devalued During Ends of 2nd and 4th Quarter

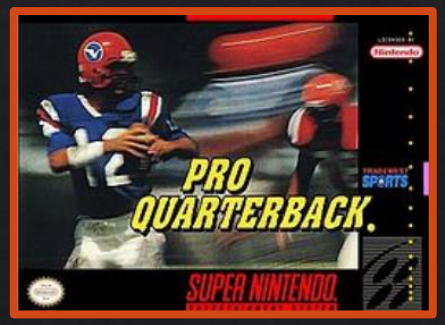
- New Defined States
  - Yard Line
  - Down
  - Yards to Go for First Down

- There is a Massive Amount of States

$$Number\ of\ States = 99 \times 4 \times 30 = 11{,}880$$

Football States and Values

- Value of a State = Margin By Which a Team is Expected to Win
- Historical Research in This Area
  - First Explored by Virgil Carter and Robert Machol (1971)
  - Modified in *Hidden Game of Football* (Carroll et Al., 1989)
  - Studied for 1st Downs by David Romer (2002) and Footballoutsiders.com
  - Estimated Value by Cabot, Sagarin, and Winston
- Analysis Done from Different Time Periods (1969 to 2006)
- Cabot, Sagarin, and Winston Used a Video Game *Pro Quarterback*



Football States and Values

Comparison of Research on State Values

NFL State Values

Yard Line	Carter and Machol	Cabot, Sagarin, and Winston	Romer*	Football Outsiders.com*
5	−1.25	−1.33	−0.8	−1.2
15	−0.64	−0.58	0	−0.6
25	0.24	0.13	0.6	0.1
35	0.92	0.84	1.15	0.9
45	1.54	1.53	1.90	1.2
55	2.39	2.24	2.20	1.9
65	3.17	3.02	2.8	2.2
75	3.68	3.88	3.30	3.0
85	4.57	4.84	4.0	3.8
95	6.04	5.84	4.90	4.6

Approaching Opponent's Goal Line

Football States and Values

- Takeaways from Analysis
  - Simulation in Video Game Allowed Data For Scenarios Other than 1st Down
  - Romer Discovered Teams Should Go on Fourth Down in Most Situations
  - Over NFL Season There are 40,000 Plays
  - This Proves That Estimated Value of States Has Considerable Error

- Simplified Scenario
  - Football Field is 7 Yards
  - Need to Get 1 Yard to Get a First Down
  - Only Have 1 Play to Get a First Down
  - We Have 50% Chance of 1 Yard and 50% Chance of 0 Yards
  - When Scored, We Get 7 Points and Opponent Starts on 1 Yard Line
  - No Field Goals or Punts

My Goal	Yard 1	Yard 2	Yard 3	Yard 4	Yard 5	Opponent Goal

Football States and Values

- Estimating Value of Each States
  - There are 5 States
  - Expected Value of Points for Each State

$$Expected\ Value\ at\ i\ Yard\ Line = V_i$$

  - Equations For Expectation (Law of conditional Expectation)

$$V_1 = 0.5 \times V_2 - 0.5 \times V_5$$
$$V_2 = 0.5 \times V_3 - 0.5 \times V_4$$
$$V_3 = 0.5 \times V_4 - 0.5 \times V_3$$
$$V_4 = 0.5 \times V_5 - 0.5 \times V_2$$
$$V_5 = 0.5 \times (7 - V_1) - 0.5 \times V_1$$

Scoring Gives the Ball to Other Team

Failing Gives the Ball to Other Team

My Goal	Yard 1	Yard 2	Yard 3	Yard 4	Yard 5	Opponent Goal

Football States and Values

- Estimating Value of Each States
  - Values Can Be Estimated Through Solving Equations
  - System Can Be Solved = 5 Variables and 5 Equations

$$V_1 = -5.25$$
$$V_2 = -1.75$$
$$V_3 = 1.75$$
$$V_4 = 5.25$$
$$V_5 = 8.75$$

- Each Yard Line Increases Expectation by 3.5 Points
- Is There Anything Particularly Unusual About This Methodology?

My Goal	Yard 1	Yard 2	Yard 3	Yard 4	Yard 5	Opponent Goal

Football States and Values

- Modification for Punts
  - Probability of Punting if 5, 4, 3, 2, 1 Yards Away is 0.9, 0.8, 0.2, 0.05, 0
  - When Punting, the Punter Kicks the Ball 1,2,3,4 Yards Away Approximately 0%, 5%, 10%, and 85% of the Time
  - Equations for Expectation

$$V_1 = 0.9[-0 \times V_4 - 0.05 \times V_3 - 0.1 \times V_2 - 0.85 \times V_1] + 0.1[0.5 \times V_2 - 0.5 \times V_5]$$
$$V_2 = 0.8[-0 \times V_3 - 0.05 \times V_2 - 0.95 \times V_1] + 0.2[0.5 \times V_3 - 0.5 \times V_4]$$
$$V_3 = 0.2[-0 \times V_2 - 1 \times V_1] + 0.8[0.5 \times V_4 - 0.5 \times V_3]$$
$$V_4 = 0.05[-1 \times V_1] + 0.95[0.5 \times V_5 - 0.5 \times V_2]$$
$$V_5 = 0.5 \times (7 - V_1) - 0.5 \times V_1$$

My Goal	Yard 1	Yard 2	Yard 3	Yard 4	Yard 5	Opponent Goal

Final Inspiration

This is no democracy.
It is a dictatorship.
I am the law.

- Coach Herman Boone