



# Football III

Produced by Dr. Mario | UNC STOR 538



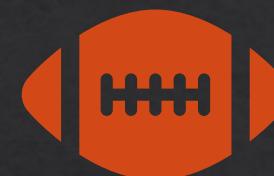
# Football States and Values



- ❖ **Advantages of States**
  - ❖ Recall: Use in Baseball
  - ❖ Purpose: To Evaluate Expected Outcome and Winning Probability from Different Strategies
  
- ❖ **Purpose in Football**
  - ❖ Analyze the Effectiveness of Offensive Plays
  - ❖ Determining Strategies on Fourth Down
  - ❖ Picking Defense Formations to Restrict Opponent



# 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

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

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 2<sup>nd</sup> and 4<sup>th</sup> Quarter

- ❖ **New Defined States**

- ❖ Yard Line
- ❖ Down
- ❖ Yards to Go for First Down

- ❖ **There is a Massive Amount of States**

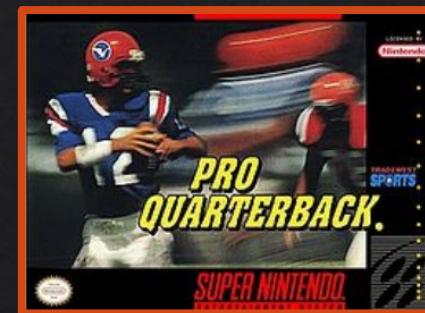
$$\text{Number of States} = 99 \times 4 \times 30 = 11,880$$



# 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 1<sup>st</sup> 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 1<sup>st</sup> 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

The Browns ruin careers,  
Like ACL tears.

- DJ Mario