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**

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

Assumption About Yards to Go

Assumption Score Differential

Assumption About Time Remaining

Football States and Values

❖ **Needs Simplification**
   ❖ Maximize the Expected Point Spread
   ❖ 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 (1981)

❖ **Analysis Done from Different Time Periods (1969 to 2006)**

❖ **Cabot, Sagarin, and Winston Used a Video Game *Pro Quarterback***
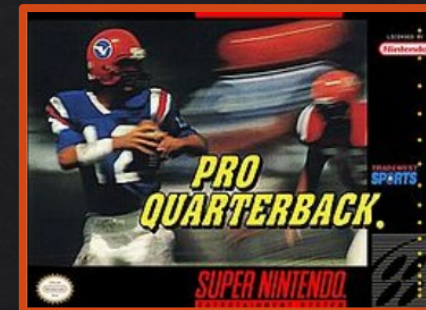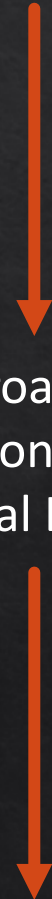
Football States and Values

❖ **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

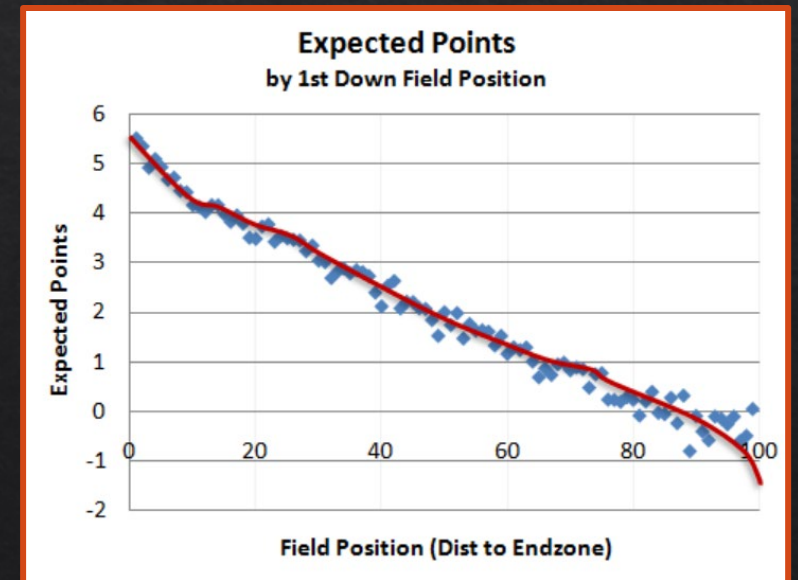Approaching Opponent's Goal Line

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

❖ **Updates from Brian Burke (ESPN)**
  ❖ See Link on Website
  ❖ "Who Scored Next?"
  ❖ Ignored Data When |Margin| > 10
  ❖ Ignored Data in 2nd and 4th Quarter
  ❖ Argue: This Removes the Impact of Time

Expected Points
by 1st Down Field Position

(y-axis: Expected Points, from -2 to 6; x-axis: Field Position (Dist to Endzone), from 0 to 100)

Football States and Values

❖ **Paper by Yurko, Ventura, and Horowitz (2019)**
  - ❖ Used a Multinomial Logistic Regression Model
  - ❖ Estimated Probability of the Next Scoring Event
  - ❖ Calculate Expected Points from this Model
  - ❖ Example

$$E[Margin] = 0.3 * 6 + 0.4 * (-6) + 0.2 * 3 + 0.1 * (-3)$$

❖ **Simplified Scenario (Method Used by CSW)**
  - ❖ 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 |

❖ **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

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

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

❖ **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