Modeling Soccer Dynamics and Predicting Scores with Potential Functions

Adhvaith, Sifan, Nick

Advisor : Kostas Pelechrinis

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Introduction / Motivation

- To encapsulate the complex movement and forces acting on the ball into a much simpler, useful object
- Use this to approximate final game outcomes
- $ $ $

StasbombR Data

team	time	type	location.x	location.y
Barcelona	00:02:40.501	Dribble	66.2	11.1
Barcelona	00:00:37.890	Foul Committed	57.2	66.3
Getafe	00:01:39.139	Interception	27.7	41.8
Valencia	00:48:06.967	Offside	86.3	23.9
Barcelona	00:00:00.229	Pass	61.0	40.1
Barcelona	00:11:44.435	Shot	93.2	44.4

Data provided by Statsbomb

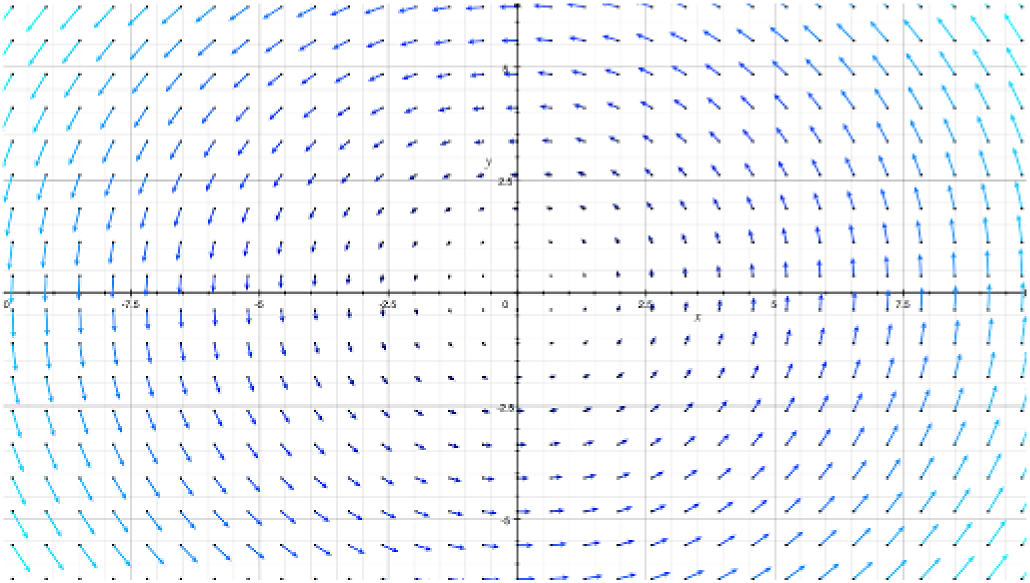
Random Walk

A sequence of some steps in random directions on some mathematical space.

- A point randomly moves along the integer line
- A point randomly moves on x-y plane

Potential Function

- Idea: The ball is a randomly drifting ball that is attracted to the goal by some "force".



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Potential Function

- We can try to model this underlying force based on the movements of the ball
- Our Potential Functions
    - Gravity

$$V(x, y) = -\frac{G}{\sqrt{x^2 + y^2}}$$

Random Walk under Harmonic Potential Function

Using potential function as a guidance for random walk

- A step by the random particle under a force.

$$r(t_{i+1}) - r(t_i) = -\nabla V(r(t_i))(t_{t+1} - t_i) + \sigma\sqrt{(t_{i+1} - t_i)}Z_{i+1}$$

- Small_Change = Estimated_Velocity x TimeStep + Noise

Learning Potential Functions from Trajectories

- Learning a Potential Function from a Trajectory - Brillinger
- Assumptions
  - Overdamped system, so force affects the velocity, not acceleration.
  - $V(x, y)$ can be approximated as a linear combination of basis functions

The Basis Functions

- Our basis functions are a set of gravitational points on the field
- The Coefficients Scale the strength of the hole (Attractive or Repulsive)

$$V(x_i, y_i) = \sum -\frac{\beta_i}{\sqrt{(x - x_i)^2 + (y - y_i)^2}}$$

Overview of the Potential Fitting Model

$$V(x,y) = \phi(x,y)^T\beta$$

$$Force = -\nabla V(x,y) = -\nabla\phi(x,y)^T\beta$$

$$\phi(x,y) = [a(x,y), b(x,y), c(x,y)]^T$$

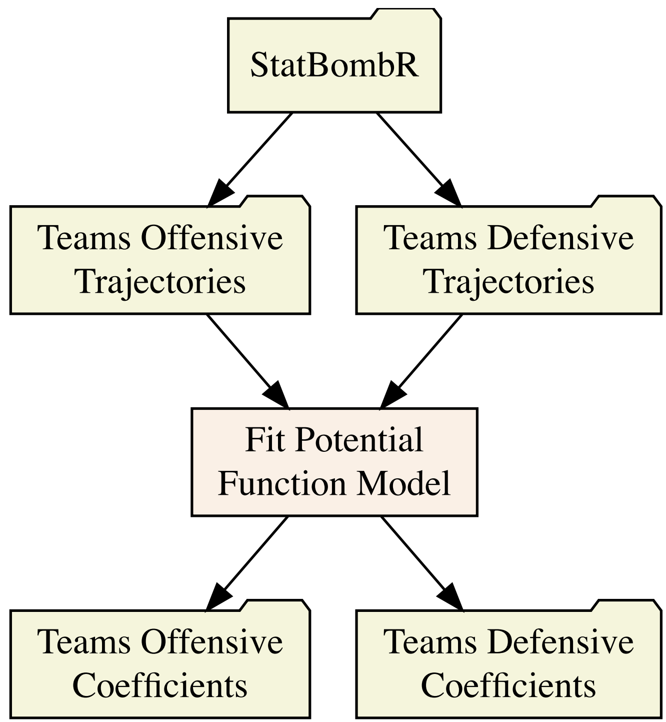
$$Velocity \sim Force$$

$$\frac{dx}{dt} = \beta_1 a_x + \beta_2 b_x + \beta_3 c_x$$

$$\frac{dy}{dt} = \beta_1 a_y + \beta_2 b_y + \beta_3 c_y$$

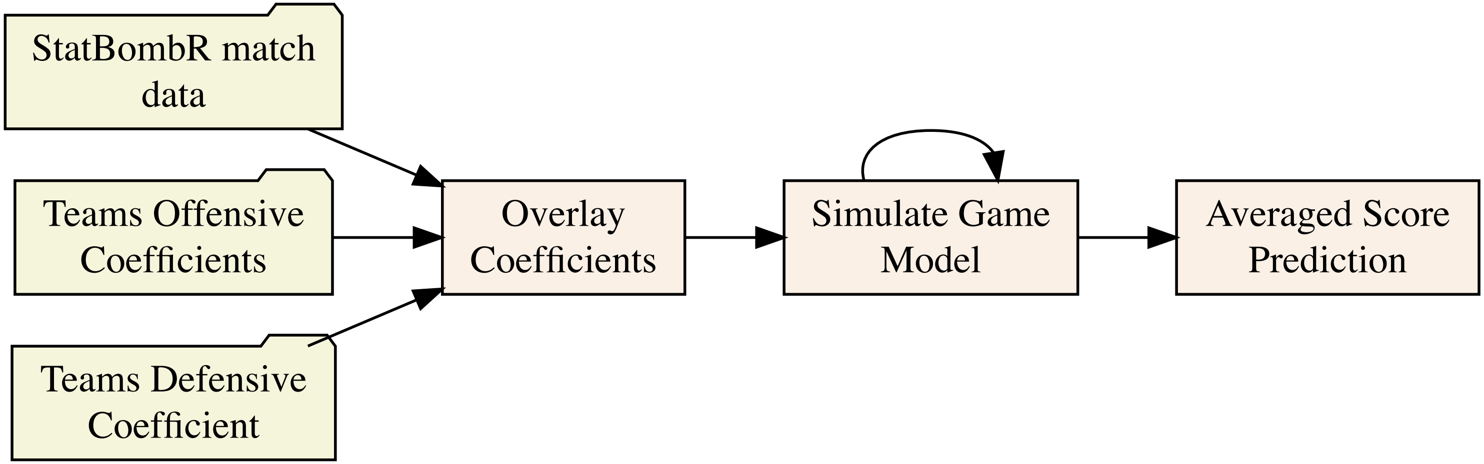
In essence, the fitting the potential is just two simple linear regression models.

Learning Potential Functions from Trajectories



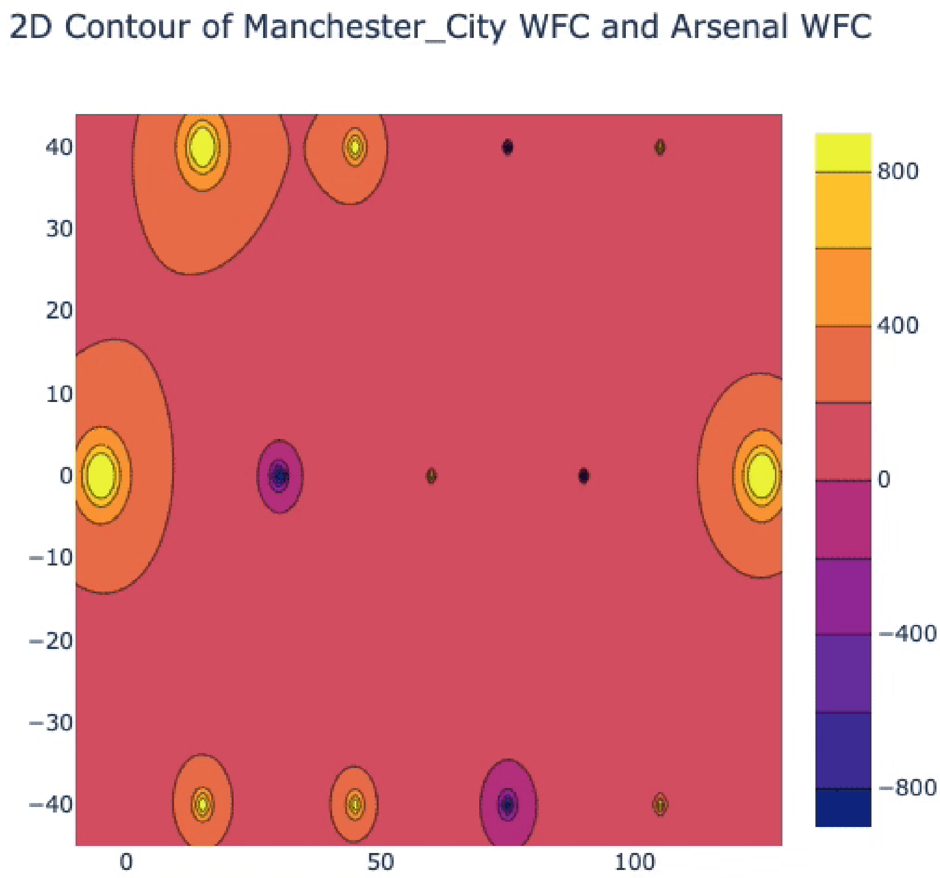
Simulating Games using the learned Potential Functions

- Overlay the potential coefficients (additive) and simulating



Potential Surface Contour

- Contour Map of Arsenal's Defensive and Manchester's Offensive
- Showing the maps change over time

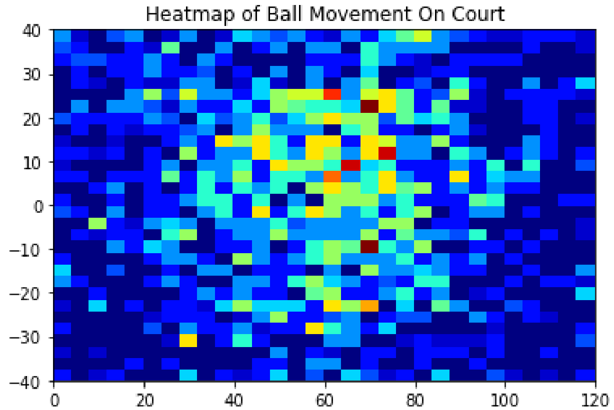


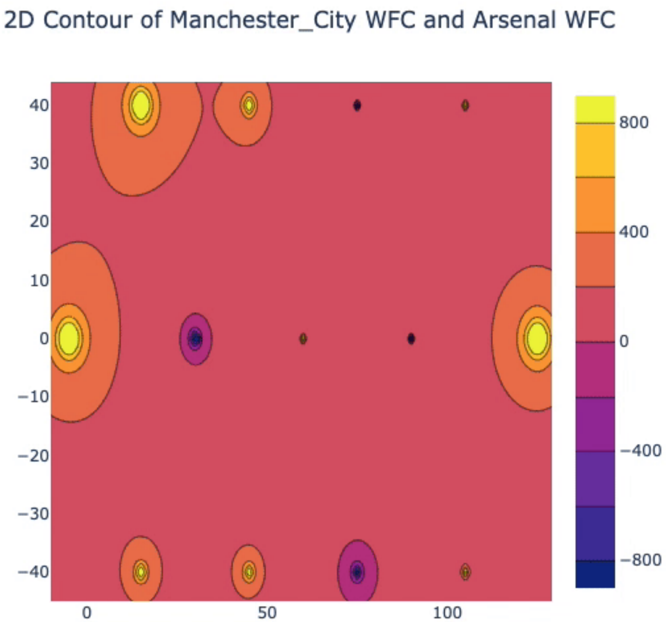
3D Potential Function

- Contour Map of Arsenal's Defensive and Manchester's Offensive
- Showing the maps change over time

Simulating the Game with the changing

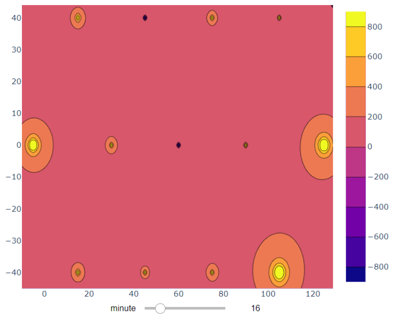
- Heatmap of the simulated Game Trajectory

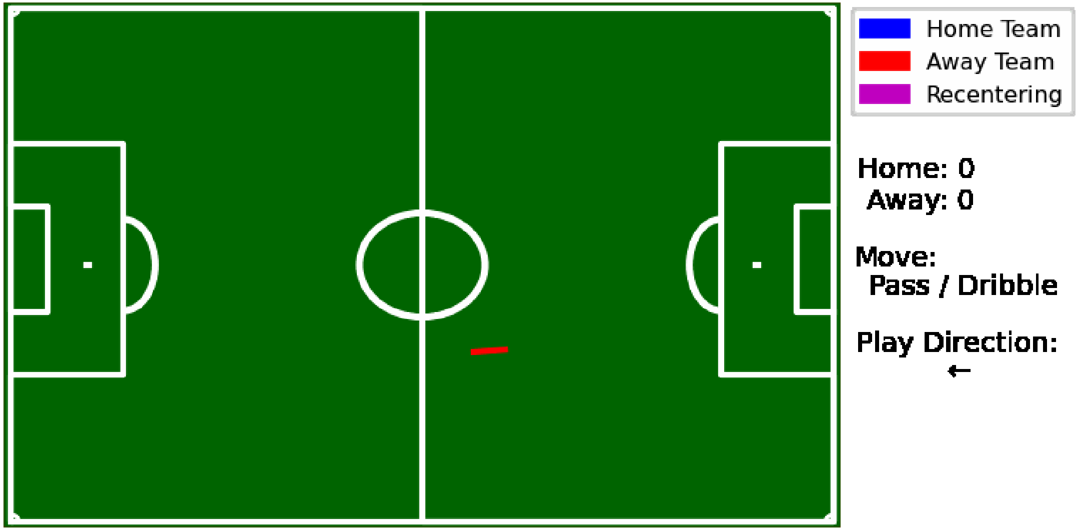




Simulated Game Gif

- Manchester City WFC (Home) vs Arsenal WFC (Away)
- Score at Minute 17





Web App to Generate Simulations

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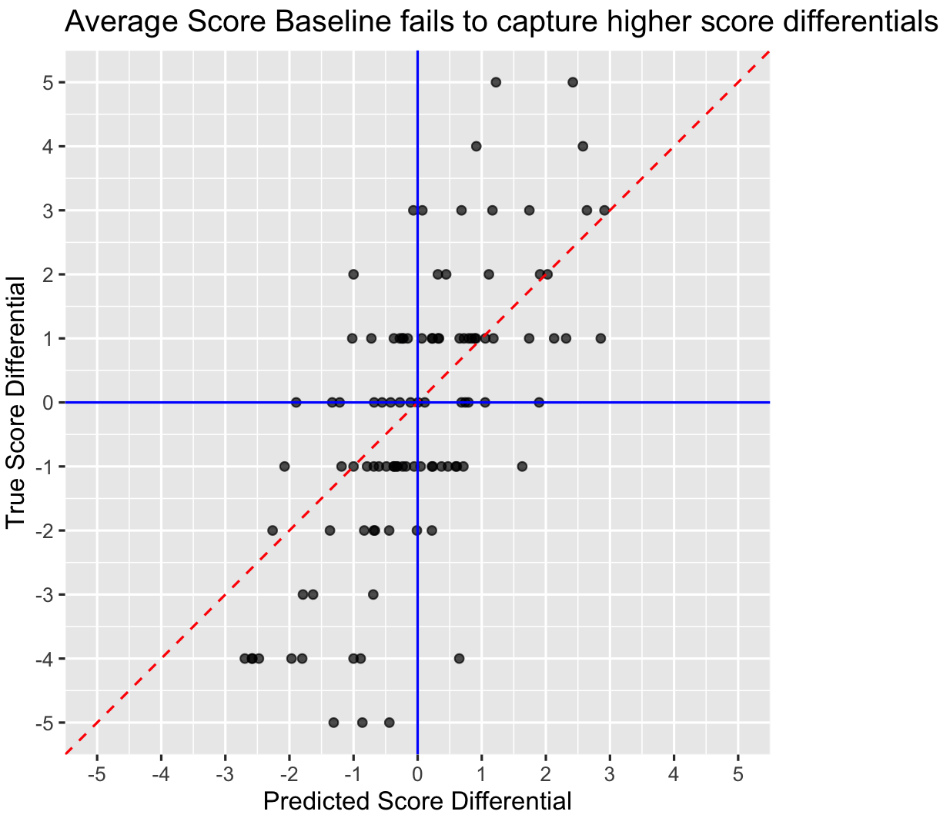
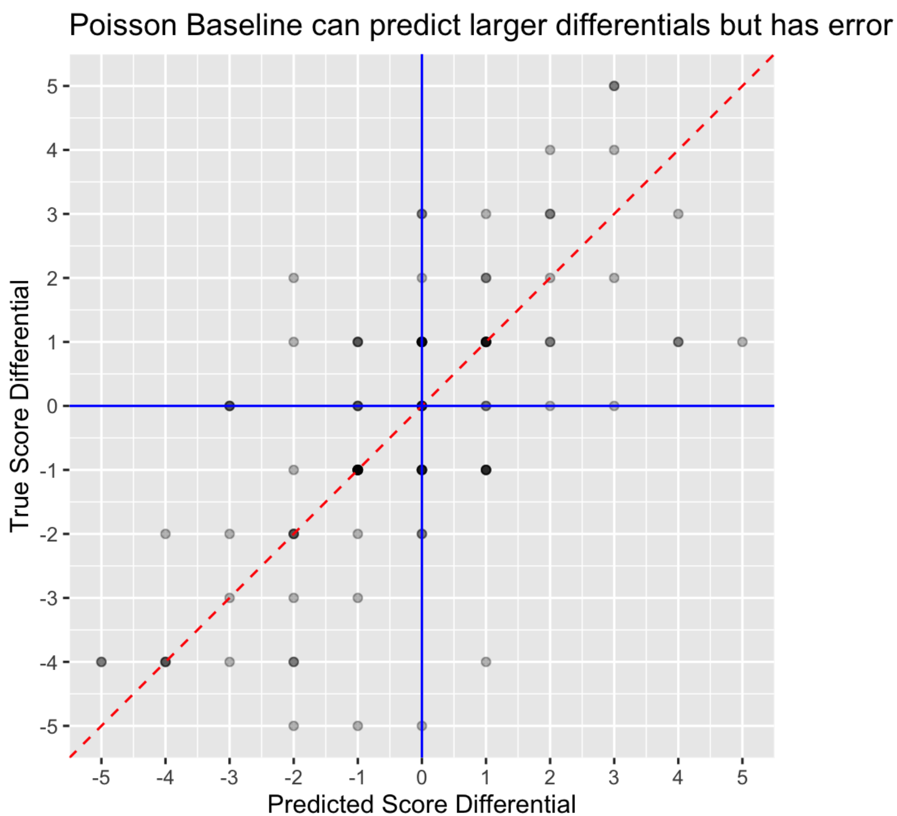
Other Baseline Comparisons

- Average has an MSE of 3.597692
- Fails to capture higher score differentials



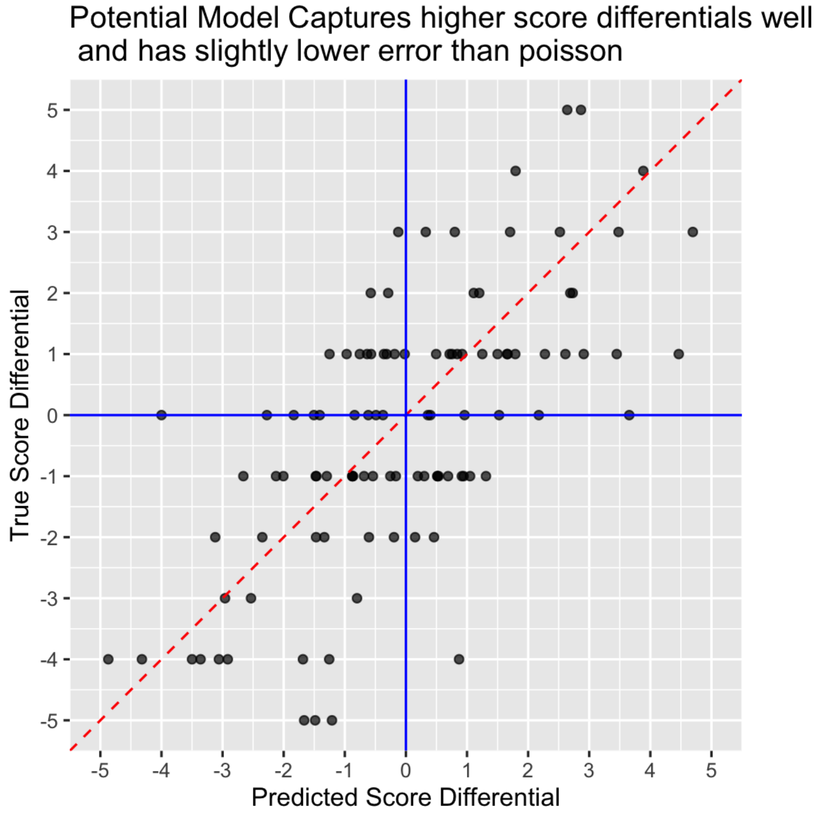
Other Baselines and Our Results

- Poisson has an MSE of 3.607477
- Categorical GLM fit with Poisson Family, covariates are home, team and opponent.



Other Baselines and Our Results

- Our model MSE = 3.379572 after 200 sims per game
- Arrives at the same conclusions as models trained exclusively on the data.



Discussion and Future Work

- A proof of concept that potential functions can capture team dynamics, as can be seen by the score predictions.
- Lots of potential to improve the framework with more accurate sub-models
    - Shot Decision model and Goal Decision model
    - Incorporate team formation and score differential into the potential function
- This framework can be used to determine other things such as:
    - Player-based potential functions to determine player impacts
    - Real-Time Game Evaluation

Appendix: Game Simulation