

Calculating Vector Accelerations Using American Football GPS Data

ECON 5253 Final Project

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Introduction

- American Football GPS Data
 - Provides raw positional data for each athlete
 - Sampled at 10 Hz (10 observations per second)
 - Currently used primarily to monitor workload and performance indicators
 - The NFL is working to bridge the gap between GPS data and football analytics (Big Data Bowl)
 - Possible applications include In-game decision-making, roster construction and draft analytics
- Vector Accelerations
 - The data includes scalar acceleration, so magnitude without respect to the direction of movement.
 - Goal: calculate acceleration vectors with respect to the athlete's orientation and movement.
 - Find propulsion (positive acceleration) and braking (negative acceleration) in each of the four directions
 - Forward, Backward, Left and Right
 - This approach provides more individualized insights

Data

- The raw data includes the following variables sampled at 10Hz
 - athlete_id: A uid describing the athlete being recorded
 - stream_type: Specifies whether the data was recorded via satellite positioning or local positioning
 - x: field x coordinates (meters)
 - y: field y coordinates (meters)
 - ts: POSIX time in seconds since the start of the epoch
 - cs: Observation time offset in centiseconds
 - face: the magnetic facing of the unit (degrees)
 - v: velocity (meters per second)
 - a: acceleration (meters per second per second)
 - pq: positional quality (percentage)

Data (cont.)

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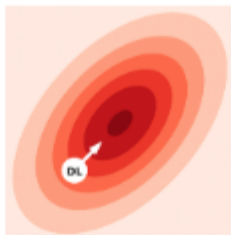
Defensive Player Influence Model

$$I_{dp} \sim N(\mu, \sigma)$$

Defender's region of influence is affected by their velocity.



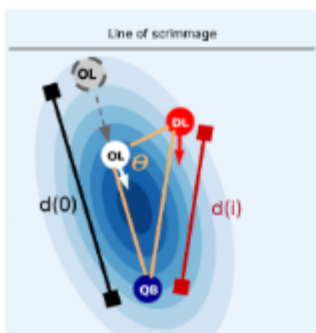
(a) At rest



(b) Player moving at 3 yd/s

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Offensive Player Influence Model



$$I_{op} \sim \frac{d(i) \cdot \Theta \cdot N(\mu, \sigma)}{180 \cdot d(0)}$$

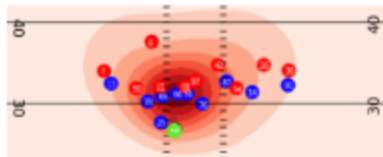
- The normalized distance between defensive lineman and the quarterback as well as the angle between the QB, OL and DL is used to scale the offensive player's influence.

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Defensive Team Influence Model

The defensive team's influence is the sum of each individual defender's influence.

$$DTI \sim \sum_{dp \in D} I_{dp}$$

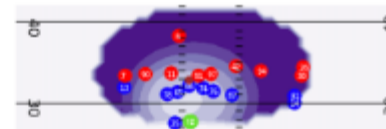


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Continuous Pressure

Intuitively, our continuous pressure metric represents the percentage of the total player influence that belongs to the defensive team at a particular location.

$$CP \sim \frac{DTI}{DTI + OPI}$$



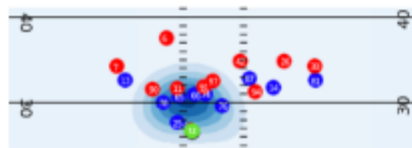
(a) Darker purple represents higher pressure

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Offensive Team Influence Model

The offensive team's influence is the sum of each offensive player's influence.

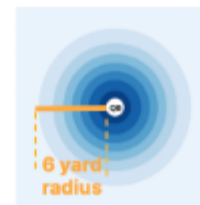
$$OTI \sim \sum_{op \in O} I_{op}$$



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Continuous Pocket Pressure

$$CPP \sim \frac{\iint N(\mu_{qb}, \sigma_{qb}) \cdot CP(x, y) \, dx dy}{\iint N(\mu_{qb}, \sigma_{qb}) \, dx dy}$$



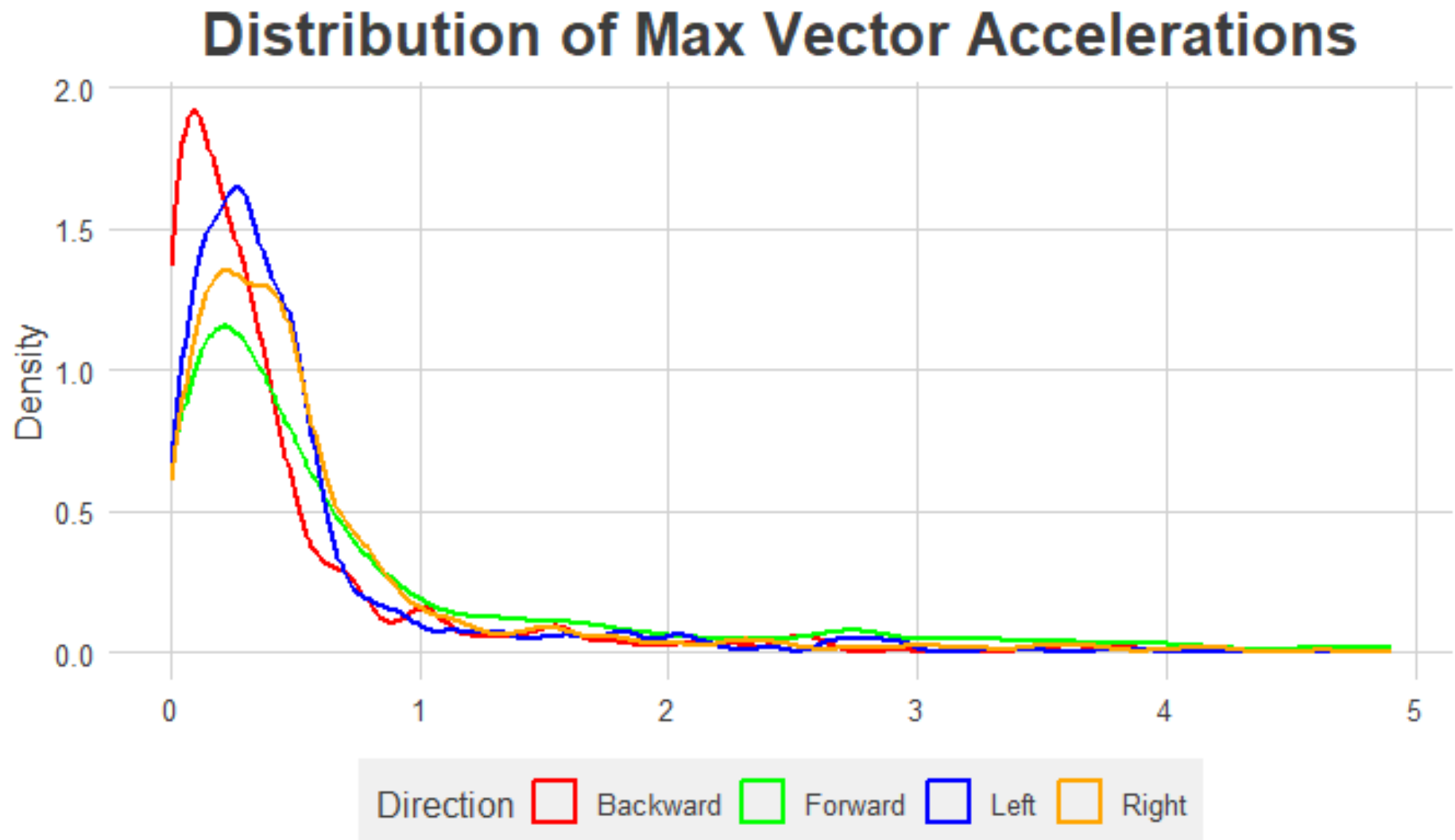
- Multiply the CP by a normal distribution centered at the QB. Then integrate over the domain of the field, and normalize the resulting CPP values so they are between [0, 1.0].

Source: Hassan Inayali, Aaron White, and Daniel Hocevar, NFL Big Data Bowl 2023

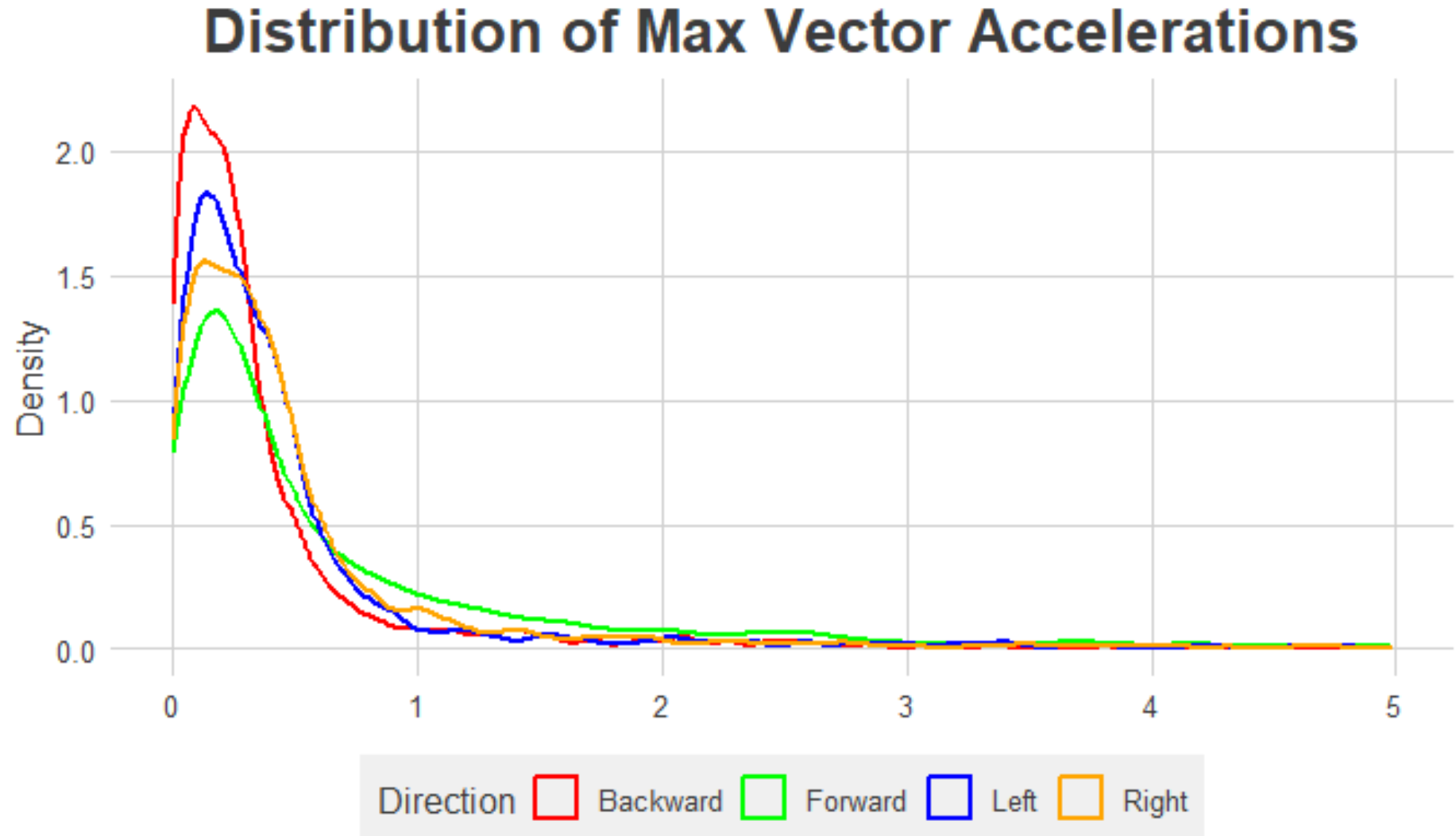
Methods

- Our vectors will be based on the difference between the direction the athlete is facing (face) and the direction they are moving.
 - First we must calculate a new variable alpha, which represents the direction the athlete is moving.
 - Done via the two-argument arctangent function, using instantaneous change in x and y coordinates as the arguments
 - Next we calculate a new variable theta, the difference between face and alpha.
 - Now use theta to calculate a series of helper variables signaling what proportion of the current movement is in each of the four planes
 - Theta = 0 degrees would be 100% forward
 - Theta = 45 degrees would be 50% forward, 50% right, etc.
 - Simply multiply the helper variables by scalar acceleration to find local vectors.
- These local vectors can now be used in place of the scalar accelerations in pre-existing GPS summaries

Results (Running Back)



Results (Cornerback)



Discussion

By creating more specific acceleration vectors, we expand the analysis possibilities, both in terms of physical performance and in-game production. Some possible next steps:

- Physical Performance
 - Monitor specific acceleration patterns of a rehab athlete based on their injury
 - Monitor performance changes in different directions based on position groups
 - Research relationship between chronic overuse in one direction and subsequent injury
 - Research relationship between different training programs and long-term performance changes
- In-Game Production
 - Identify athletes' strengths and weaknesses in various movement types to better inform scheme and personnel decision-making
 - Which running backs and receivers cut faster toward their left/right?
 - Which defensive backs excel at backpedaling vs. forward propulsion? (Corner vs. Safety)
 - Using NFL data, research relationship between various movement types and long-term NFL success.