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A GAME THEORETIC MODEL FOR KABADDI GAME

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ABSTRACT

Kabaddi, a sport pulsating with skill, risk, and strategic tension, has captivated audiences for centuries. This study dives into the heart of this captivating game, wielding the analytical blade of game-theoretic modeling to dissect the intricate strategic interplay between raiders and defenders. We present a novel escape probability function, meticulously crafted to incorporate skill, defender presence, and strategic nuances, reflecting the dynamic realities of the court. Our model sheds light on the dynamic interplay within and across raid types. Raiders prioritize maximizing touches in regular raids, while defenders strive for tackles. This dance intensifies in do-or-die situations, where defenders adopt cautious approaches and the raider becomes increasingly aggressive. Further, we unveil the strategic flexibility woven into the model, allowing for exploration of diverse tactics and their impact on escape probabilities. By unveiling the intricate web of strategies within Kabaddi, this study provides a novel framework for understanding and optimizing player decision-making. Our tool and data-driven insights empower both coaches and players to navigate the ever-shifting terrain of this dynamic sport, leaving their mark on the legacy of Kabaddi.

KEYWORDS: Raider, Defender, Kabaddi, Nash equilibrium.

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RESUMEN

El kabaddi, un deporte que combina habilidad, riesgo y tensión estratégica, ha cautivado al público durante siglos. Este estudio se sumerge en el corazón de este cautivador juego, usando, como herramienta, la teoría de juegos para diseccionar la intrincada interacción estratégica entre asaltantes y defensores. Presentamos una novedosa función de probabilidad de escape, meticulosamente diseñada para incorporar habilidad, presencia del defensor y matices estratégicos, reflejando su naturaleza dinámica. Nuestro modelo brinda una mejor descripción de la interacción dinámica dentro y entre los tipos de bandas. Los asaltantes priorizan maximizar los toques en las incursiones regulares, mientras que los defensores se esfuerzan por las tacleadas. Esta danza se intensifica en situaciones de vida o muerte, donde los asaltantes adoptan enfoques cautelosos y los defensores se vuelven cada vez más agresivos. Además, revelamos la flexibilidad estratégica entretejida en el modelo, lo que permite explorar diversas tácticas y su impacto en las probabilidades de escape. Al desvelar la intrincada red de estrategias dentro de Kabaddi, este estudio proporciona un marco novedoso para comprender y optimizar la toma de decisiones de los jugadores. Nuestra herramienta y nuestros conocimientos basados en datos permiten tanto a los entrenadores como a los jugadores navegar por el terreno siempre cambiante de este deporte dinámico, dejando su huella en el legado de Kabaddi.

PALABRAS CLAVE: Asaltantes, Defensores, Kabaddi, Equilibrio de Nash.

1. INTRODUCTION

Kabaddi, one of the ancient games of India, is also one of the most popular games in the Indian subcontinent. It is known by different names in different regions, such as Chedugudu in Andhra Pradesh, Ha-du-du in Bangladesh, Bhavatik in Maldives, Kauddi in the Punjab region, Hu-tu-tu in western India, Hu-do-do in Eastern India, Chadakudu in south India and Kapardi in Nepal [1, 2, 3]. Additionally, Kabaddi is the national sport of Bangladesh. It is a two-team competitive sport played on a court measuring 10m×13m, which is divided into two equal halves by a mid-line. The essential components of the Kabaddi court include the baulk line, bonus line, end line, and lobby. The objective of the raiding team is to touch or tag as many players of the defending team as possible and return to their court without getting caught by the defenders. On the other hand, the defending team aims to protect themselves from getting tagged and catch the raider before they reach their court. Each raid is crucial as it determines the number of points earned by the raiding team. Moreover, a successful raid is one in which the raider returns to their court without getting caught, while an empty raid is when the raider returns without tagging any opponent. A do-or-die raid is declared if a team makes two consecutive empty raids, which means the raider must tag a defender in their third raid, or they will be automatically declared out. The game of Kabaddi requires strategic thinking, skill, and analysis, making it an ideal candidate for analysis using game theory [6]. Although several attempts have been made to model the game, very few have considered the strategic aspect of the game [4, 5, 7]. Swati Singh and her co-author have attempted to model the game by assuming that the defender can tackle the raider using one of the five strategies: back hold, ankle hold, thigh hold, block, and dash. Similarly, the raider can choose from five strategies: toe touch, hand touch, front kick, back kick, and dubki [8]. However, this model fails to capture the strategic aspect of the game, which is dependent on the distance of the raider from the middle line at the time of the attack. In this paper, the author

has proposed a more realistic and probabilistic approach to model the game, taking into account the strategic aspect of the game, which is dependent on the distance from the middle line. The skill level of professional Kabaddi players is high, and they are well aware of their strengths and weaknesses, but the most critical question of when to attack the opponent requires a game-theoretic approach.

2. THE MODEL

Kabaddi, a sport rooted in Indian tradition and now embraced globally, captivates audiences with its unique blend of athleticism, strategy, and anticipation. At the heart of this exhilarating sport lies the raid—a high-stakes encounter where a lone raider ventures into enemy territory, seeking to score points by tagging opponents and escaping unscathed. This dynamic interplay between a raider's agility and a team's defensive coordination presents a fascinating arena for game-theoretic analysis. To explore the optimal decision-making strategies within this context, we construct a simulation model that captures the essence of the Kabaddi raid, delving into the factors that influence success and the equilibrium strategies that emerge under various scenarios.

- **Players:**
  - **Raider (R):** Aims to evade defenders and touch them within the opponent's court, scoring points for each touch.
  - **Defender (D):** Collaborate to tackle and restrain the raider within their own court, preventing scoring.
- **Strategies:**
  - **Raider:**
    - **Passive (P):** Focuses on evasive maneuvers and calculated touches.
    - **Aggressive (A):** Employs high-risk, high-reward tactics seeking multiple touches or bonus points.
  - **Defender:**
    - **Passive (P):** Prioritize team formation and coordinated tackling.
    - **Aggressive (A):** Emphasize individual tackling efforts and quick reactions.

2.1. Escape Probability

This key element reflects the raider's success in evading tackles based on skill, the number of defenders (n), and their chosen strategies. We propose a function incorporating these factors:

$$P(escape) = floor_{prob} + (max_{prob} - floor_{prob})(1 - penalty)$$

where

- $floor_{prob}$: *Minimum escape probability even for unskilled raiders.*
- max_{prob} : *Maximum escape probability for a highly skilled raider with no defenders.*
- *penalty* : *Function reflecting the impact of defenders and strategies, increasing with n and varying based on chosen tactics.*

Our penalty function, shown below, factors in the raider's skill, number of defenders, and both strategic choices, directly influencing the escape probability.

$$penalty = 0.5(1 - \delta)(1 - \frac{2}{1+n})\eta_R\eta_D$$

where

- δ : *Raider skill*
- n : *Number of Defenders involved actively*
- η_R : *Raider modifier*
- η_D : *Defender modifier*

2.2. Explanation of the Penalty Function

- Base penalty: $0.5(1 - \delta)$
  - *Starts at* 0.5 *for unskilled raiders and decreases towards 0 for highly skilled raiders, reflecting their ability to evade tackles.*
- Defender penalty: $(1 - \frac{2}{1+n})$
  - *Increases with the number of defenders n, but at a diminishing rate, capturing the effect of additional defenders while accounting for potential coordination issues.*
- Strategy modifiers: η_R *and* η_D
  - *Values between 0 and 1 adjusting the penalty based on chosen strategies, reflecting the impact of different tactics.*

The penalty function incorporates the following key features in the model:

- Incorporates skill, defenders, and strategies: *The penalty function seamlessly integrates these three elements, ensuring a comprehensive representation of factors that affect escape probability.*
- Diminishing returns of defenders: *The logarithmic nature of the defender penalty reflects the reality that adding more defenders doesn't guarantee a proportional increase in tackling effectiveness.*

- Strategic flexibility: *The strategy modifiers allow for fine-tuning the penalty based on specific tactics, enabling exploration of different play styles.*
- Bounds: *The combined penalty is guaranteed to stay between 0 and 0.5, ensuring the escape probability remains within 0 and 1.*

This penalty function provides a flexible and realistic way to model the challenges faced by the raider in Kabaddi, contributing to a more accurate simulation of the game's dynamics and decision-making processes.

2.3. Payoff Functions

In the pulsating heart of Kabaddi lies the multifaceted concept of the raid. These daring incursions by the raider, seeking touch and escape, come in two distinct flavors: the "regular" and the "do-or-die" raid. In the regular raid, success for the raider translates to points amassed through deft touches, measured against the sting of losing points for their skill if tackled. Defenders, while bearing no direct point loss for a successful raid, face the strategic cost of losing a player to the opposition bench. However, their vigilance is rewarded with a single point for each raider tackled, especially when both sides adopt aggressive tactics.
The do-or-die raid, a crucible of heightened tension, amplifies the stakes for both sides. For the raider, the point structure remains the same, but every decision reverberates with greater consequence. For the defenders, the pressure cooker simmers just a little hotter, with the reward for stopping the raider in its tracks simply enhanced to one point, a testament to the importance of their desperate stand. Now, let's delve into the mathematical heart of this strategic dance, unraveling the average expected scores for both raider and defender, offering a glimpse into the probabilistic landscapes that shape their decisions within each raid type.

- **Raider's Average Payoff:**

$$\pi_R = P(escape)k - (1 - P(escape))\delta$$

- **Defender's Average Payoff:**

$$\pi_D = P(tackle) - P(escape)k$$

where
k : Number of players raider touched $0 \leq k \leq n$.
$P(tackle)$: The probability of the defenders successfully tackling the raider.

3. DISCUSSION

This study ventured into the dynamic world of Kabaddi, wielding the analytical scalpel of game-theoretic modeling to dissect the strategic interplay between raiders and defenders. Our core tool was a novel escape probability function, meticulously crafted to capture the intricacies of this thrilling sport.

The heart of our model lies in the escape probability function, which seamlessly integrates skill, defender presence, and strategic nuances. The penalty for tackling incorporates **diminishing returns of defenders**, meaning that adding more players doesn't guarantee a proportional increase in stopping the raider. This reflects the tactical skill of raiders and the spatial dynamics of the court. Additionally, **strategic flexibility** is woven into the function, allowing for adjustments based on specific tactics like "baits" or "dives." Lastly, the function guarantees realistic escape probabilities, bounded between 0 and 1.

Beyond mere understanding, this model strives to be actionable. We are currently developing a recommendation tool that translates the model's predictions into concrete strategic pointers for both raiders and defenders. It could suggest optimal touch targets for raiders based on defender positioning and skill, while simultaneously advising defenders on effective tackling strategies and resource allocation. Our model delves deep into the defender's perspective, seeking strategies to counter various raider tactics and maximize point gains. Against an aggressive raider seeking maximum touches, the model recommend a cautious approach with emphasis on preventing escapes rather than risky tackles. Conversely, a more conservative raider could be met with a counterbalancing aggression to capitalize on their tentative movements. Ultimately, the model aims to equip defenders with a dynamic toolbox of strategies tailored to specific raider behaviors and game situations.

For the raider, the tool wouldn't simply point to specific touch targets. Instead, it would analyze the entire defensive landscape, factoring in defender skill, positioning, and strategic tendencies. Based on this dynamic assessment, it would recommend high-probability escape routes, maximizing the chances of evading tackles and racking up points.

For the defender, the tool wouldn't dictate resource allocation blindly. It would analyze the raider's skill level, attack patterns, and potential escape routes. Based on this nuanced understanding, it would suggest optimal defensive formations and tackling strategies, maximizing the chances of thwarting the raider's charge and securing crucial points.

Furthermore, the tool wouldn't operate in a vacuum. Tournament data would continuously feed the model, refining its predictions and adapting to evolving strategies. This constant learning process ensures the tool remains a dynamic and reliable companion for players and coaches navigating the ever-shifting terrain of Kabaddi.

4. CONCLUSION

In conclusion, this game-theoretic exploration unlocks a deeper understanding of Kabaddi's strategic landscape. The escape probability function serves as a key, its intricacies revealing the interplay of skill, strategies, and chance within this electrifying sport. We envision a future where this model transcends analysis, morphing into a recommendation tool that empowers both coaches and players to navigate the ever-shifting terrain of Kabaddi, etching their names in the annals of this enthralling sport.

5. FUTURE SCOPE

The ever-evolving landscape of Kabaddi demands constant adaptation. To this end, our model can be further enriched by integrating tournament data. Analyzing past matches alongside player skill profiles and team formations can empower coaches to identify optimal strategies for upcoming encounters. Players, too, can benefit from a data-driven understanding of their opponents' tendencies and develop personalized plans to counter them.

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