Topology and Soccer

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Introduction

- Soccer is Dynamic

- Spatially Complex/High-Dimensional

- Full of "subjectivity" and context-dependent

Traditional Metrics

- Number of Passes
- Completion %
- xG/xA
- Tackles
- Successful Dribbles/Dribbles Attempted
- Etc.

These metrics miss structure, context, and geometric coherence of the tactical/player identities that are relevant to the outcome of games.

Where Topology is Useful?

- Passing is an essential part of a team's success and passing can be represented as a point in high-dimensional space capturing, direction, angle, outcome, position, and technique.
- Players can be represented as point clouds of passes
- Teams can be represented as a manifold of passing behavior

Question: Can player identity and team style be represented using this geometric representation instead of the one dimensional statistics traditionally used?

Background/Related Work

Persistent Homology and Motion Data (Sweeting & Aughey)

- Argue that traditional sports metrics fail to capture full athlete behavior.
- Use geometric representations of movement trajectories to study workload and patterns.
- Emphasize clustering (k-means) rather than persistent homology for structure discovery.

Alice J. Sweeting, Robert J. Aughey, Stuart J. Cormack, and Stuart Morgan. Discovering frequently recurring movement sequences in team-sport athlete spatiotemporal data. Journal of Sports Sciences, 35(24):2439–2445, 2017. PMID: 28282752.

Background/Related Work

Applications to Soccer (Football) (Ramos & Szilamer)

- Both apply persistent homology to model team structure and tactical identity early in matches.

- Use H_0 and H_1 features to relate attacking/defensive shape to season performance.

- Natural fit for machine learning due to stable topological feature representations.

- Limitations: assumes static structure, ignores in-game adjustments, forced role changes, and formation volatility.

Mate Szilamer. Topological diversity of football teams. Medium, 2025.

Fernando Ramos and Huberto Ayanegui. Discovering tactical behavior patterns supported by topological structures in soccer-agent domains. In Proceedings of the 7th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2008), pages 1421–1424, Estoril, Portugal, May 12–16 2008
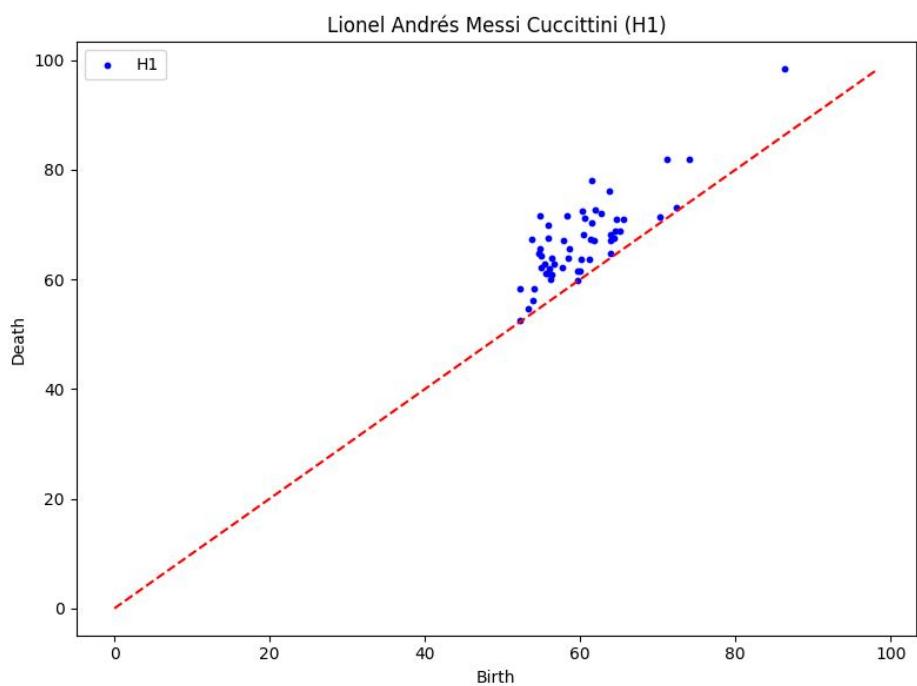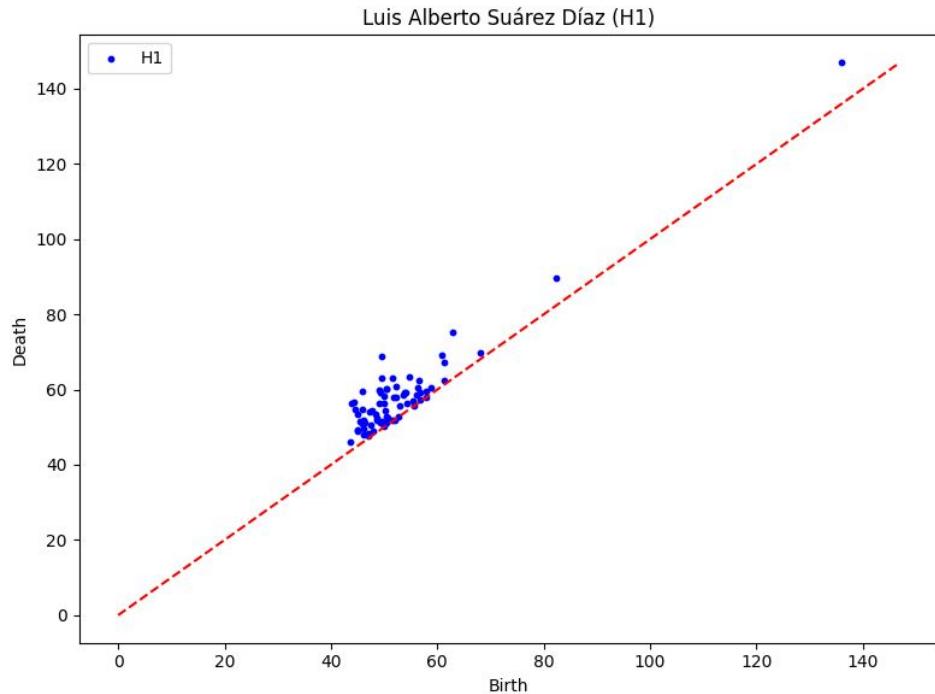
What's missing?

- **From team topology to player-level topology**

    - Most TDA work treats teams coherent systems; almost no work models individual player topology as a stable identity which is more relevant and useful for teams who are planning longer term than just the current season

- **From tactics to recruitment and compatibility**

    - Existing work focuses on formation discovery and tactical patterns; TDA has not been systematically applied to scouting, transfer evaluation, or compatibility in a current squad

- **Quantifying tactical "plug-and-play" potential**

    - No current framework estimates how quickly a player can integrate structurally into a team based on topological similarity between their role and a team's interaction network
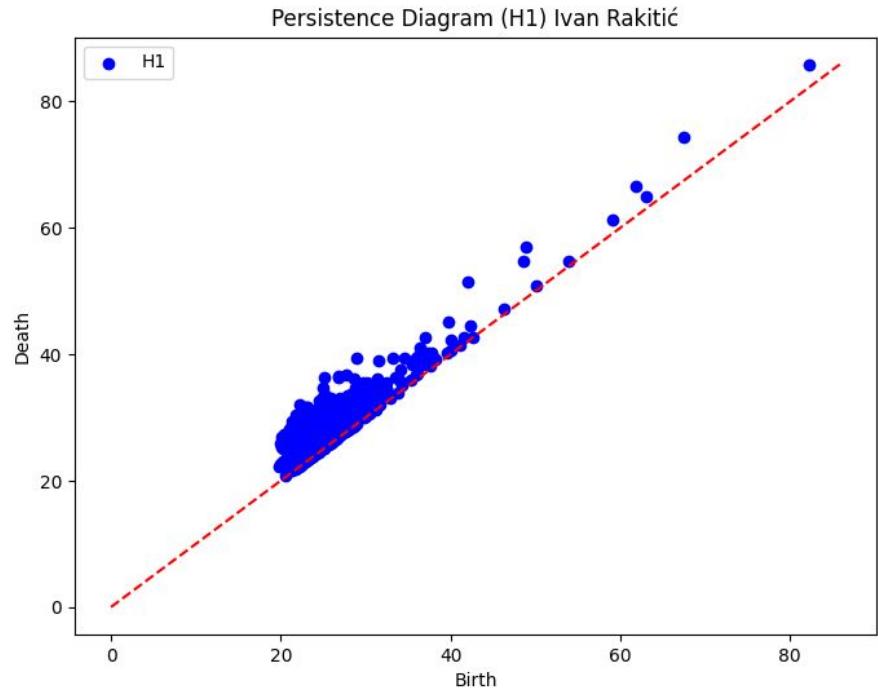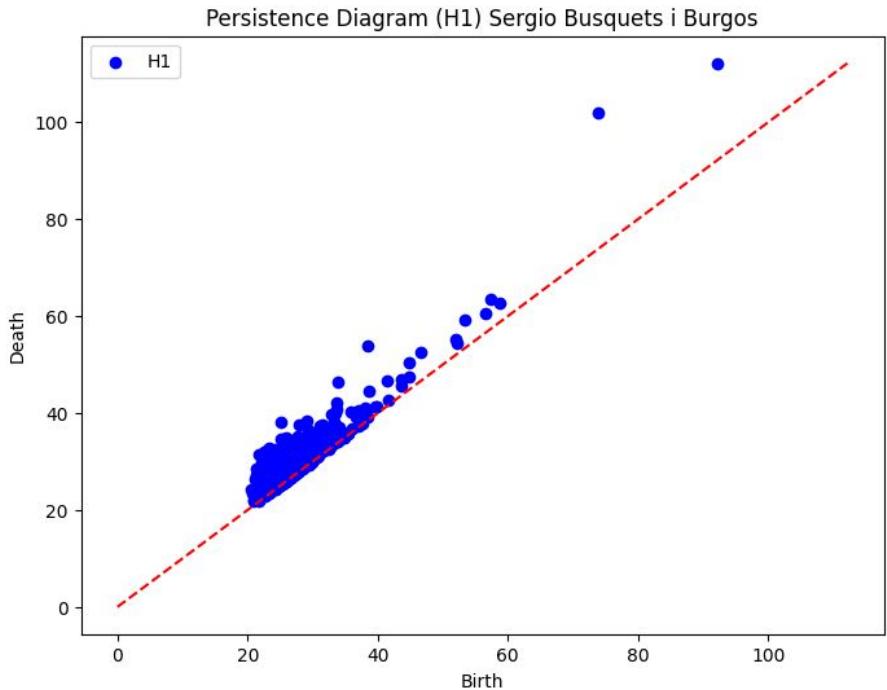
Persistence

- Encode players passing over the course of a season as high dimensional point clouds
  - Using stats-bomb data set focusing on Barcelona 2014/2015 champions league season
  - Focusing on 6 players: (Messi, Suarez)(Attackers), (Busquets, Rakitic)(Midfielders), (Pique, Dani Alves)(Defenders)
  - One 19 dimensional point represents a pass
    - [Start and End Location], [Displacement Vector], [Distance], [Pass Direction Angle]...
  - Took 100 farthest point samples to represent their passing geometry over the course of the season
- Goal: Detect loops and give meaningful soccer interpretations to these loops
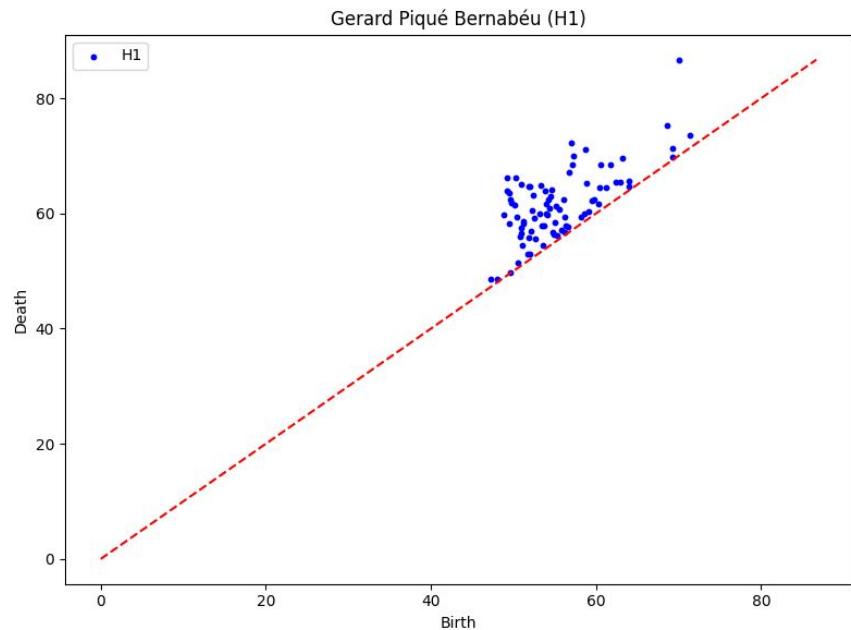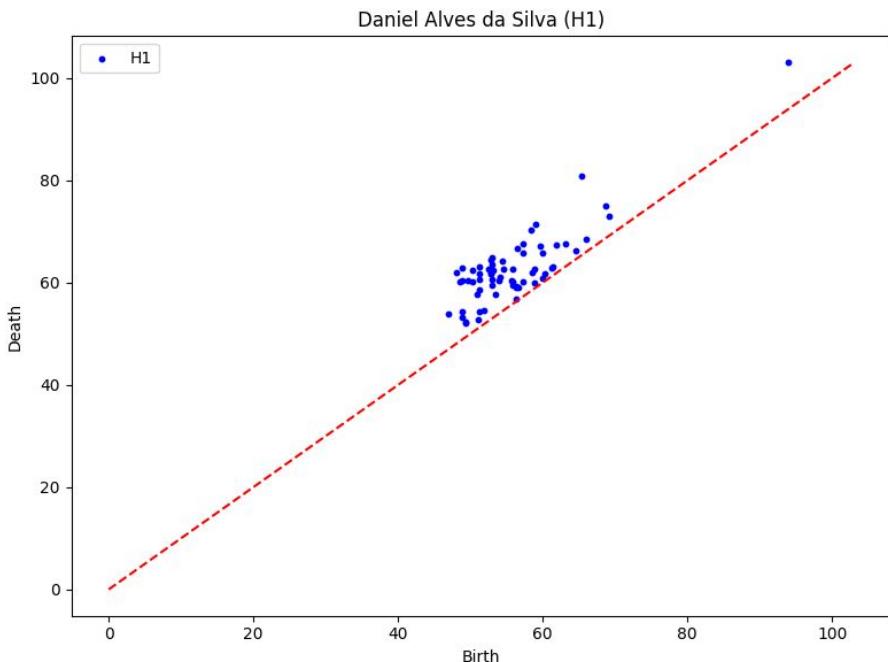
Persistence Diagrams (Attacking Players)

Luis Alberto Suárez Díaz (H1)

Lionel Andrés Messi Cuccittini (H1)

Persistence Diagrams (Midfielders)
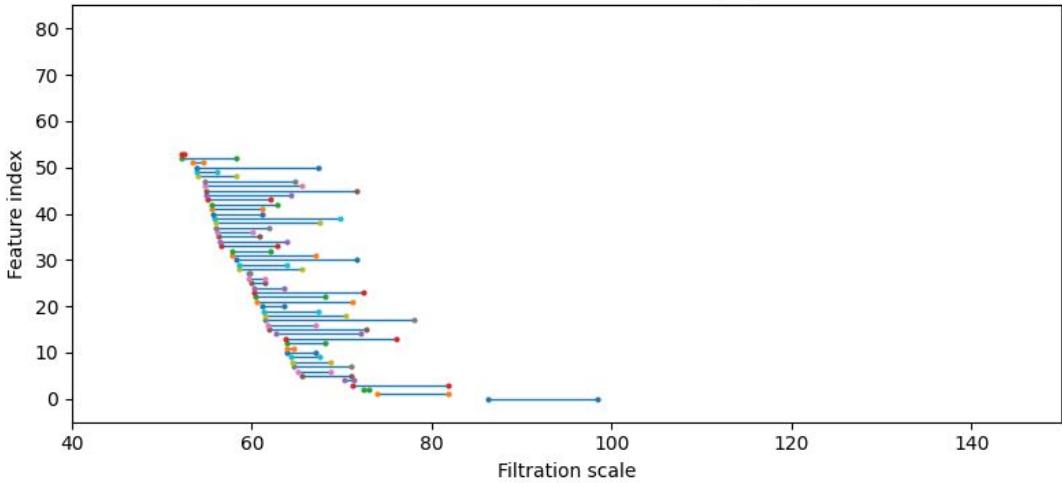
Persistence Diagrams (Defenders)
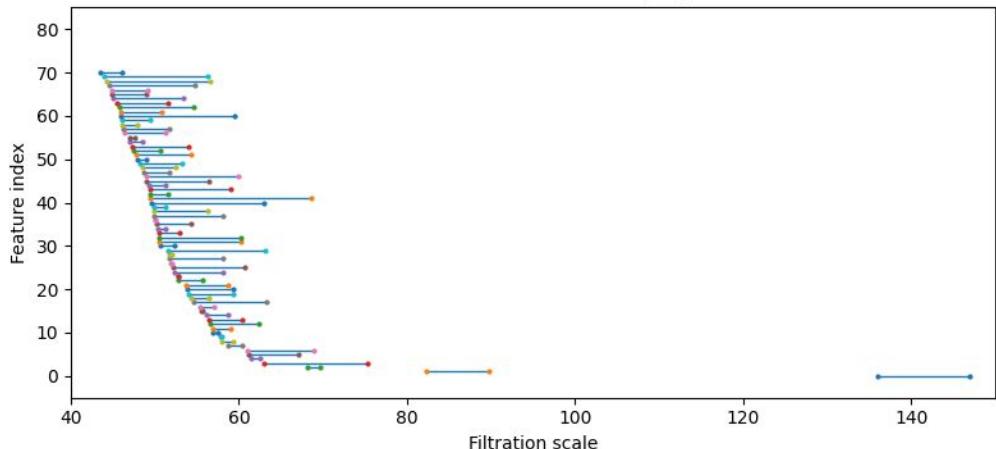
# Barcodes (Attackers)

Lionel Andrés Messi Cuccittini (H1)
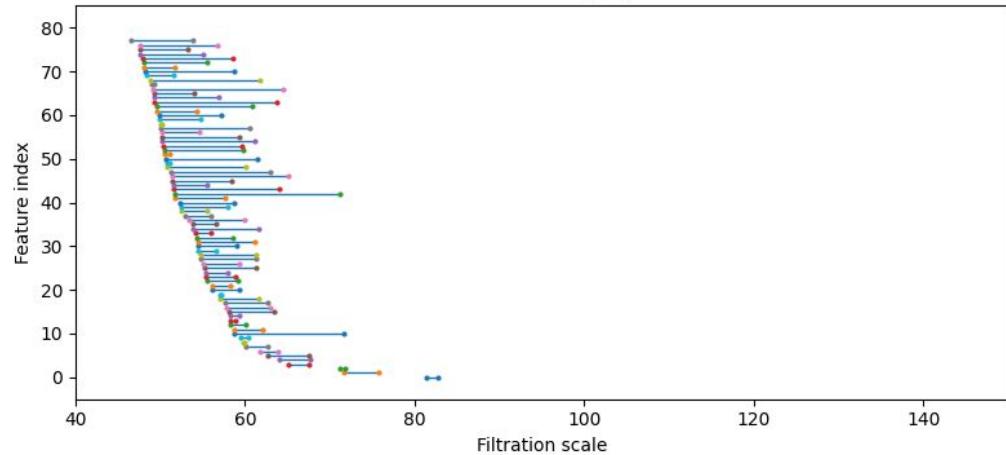
Luis Alberto Suárez Díaz (H1)
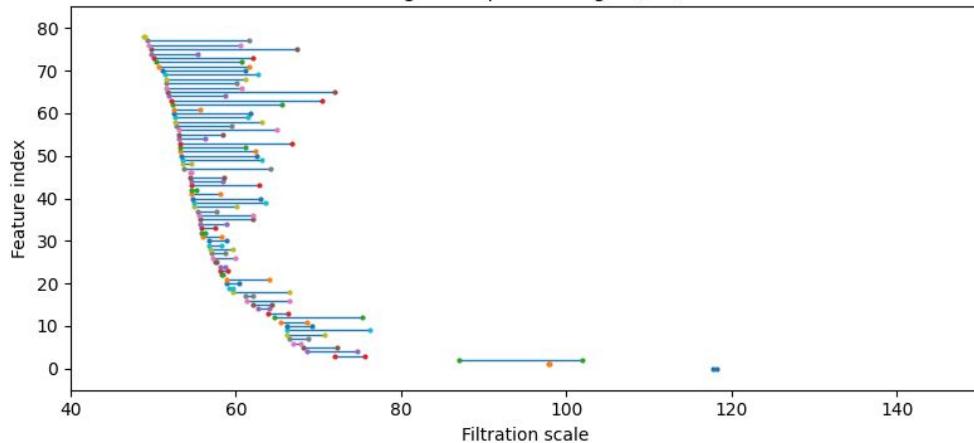
# Barcodes (Midfielders)

Ivan Rakitić (H1)
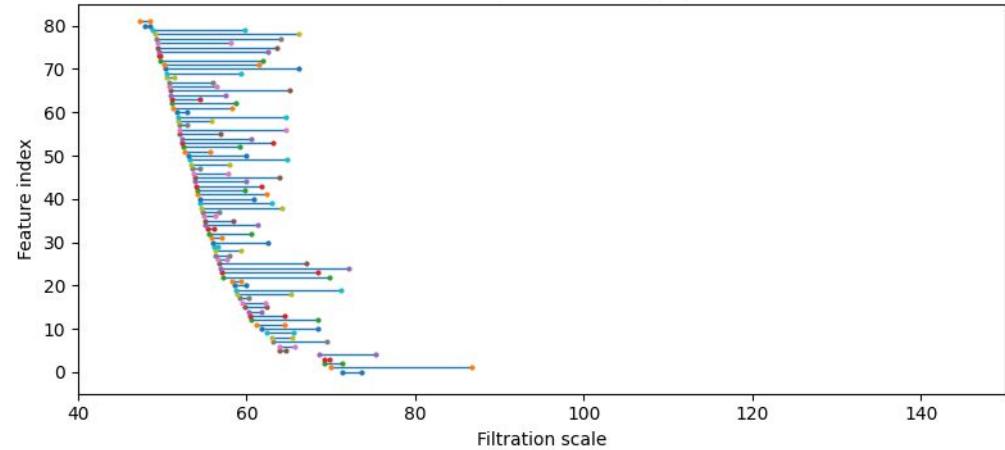
Sergio Busquets i Burgos (H1)
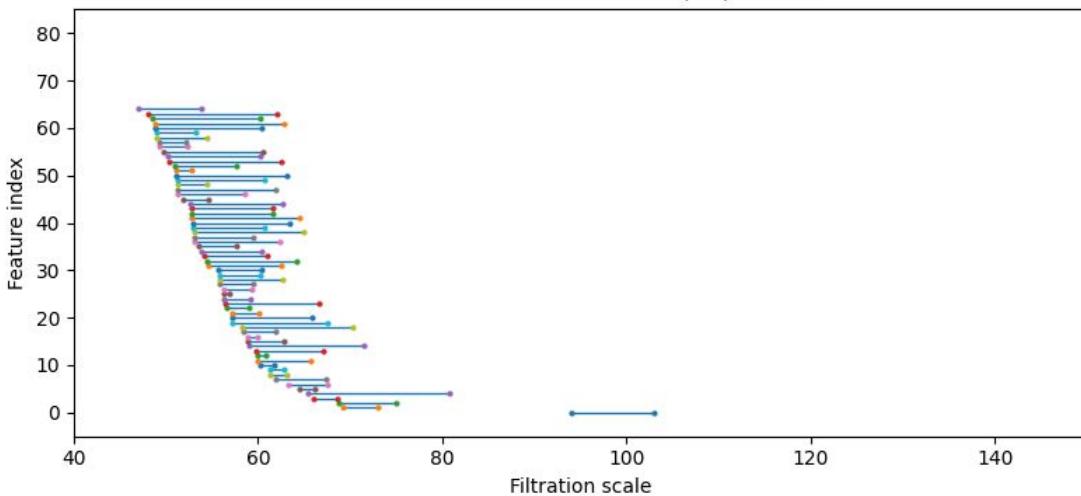
Barcodes (Defenders)

Gerard Piqué Bernabéu (H1)

Daniel Alves da Silva (H1)

Mapper Graphs

- Reduce the complexity of the space

- Reveal clusters

- Visualize how players' actions organize across different contexts