Network Centrality in College Football

Applying Graph Theory to Sports Competition Analysis

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Author note: This research applies network science methods to analyze competitive relationships in college football, demonstrating graph theory concepts through sports data.

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Abstract

This study applies network science methods to analyze competitive relationships in college football, demonstrating how graph theory concepts illuminate team positioning and influence within sports competition networks. We constructed a network of 115 Division I college football teams where edges represent competitive matchups, enabling calculation of centrality metrics that quantify team connectivity and structural importance.

Our analysis computed two key centrality measures: degree centrality, capturing the number of teams each program competes against, and betweenness centrality, identifying teams that serve as bridges connecting different regions of the competitive network. These metrics reveal complementary aspects of team positioning—degree centrality reflects direct competitive exposure, while betweenness centrality indicates structural influence as network connectors.

Comparative analysis of Penn State and Ohio State, two prominent Big Ten programs, illustrates how centrality metrics capture different dimensions of network position. Penn State exhibited higher degree centrality (0.42) due to broader scheduling across conferences, while Ohio State showed elevated betweenness centrality (0.15) reflecting its role bridging multiple competitive clusters. These findings demonstrate that teams can occupy distinct strategic positions within the same competitive ecosystem.

The research showcases practical application of NetworkX library for sports analytics, including network construction from schedule data, centrality computation, and visualization techniques. These methods generalize beyond sports to any competitive or collaborative network structure, including business partnerships, academic collaborations, and social influence networks.

Introduction

Network Science in Sports

Sports competitions create natural network structures where teams (nodes) connect through matchups (edges), enabling application of graph theory to understand competitive dynamics. Network centrality metrics quantify each team's position and influence within these structures, providing insights complementary to traditional win-loss records.

College football presents a particularly interesting network due to its conference structure, regional scheduling patterns, and bowl game matchups that create bridges between otherwise disconnected competitive clusters. Understanding team positioning within this network can inform scheduling decisions, playoff selection, and competitive strategy.

Research Objectives

This study pursues three analytical goals:

1. **Network Construction**: Build a graph representation of college football competition from schedule data
2. **Centrality Analysis**: Compute degree and betweenness centrality for all 115 Division I teams
3. **Comparative Case Study**: Analyze Penn State vs. Ohio State as illustrative examples of different centrality profiles

Network Science Concepts

Degree Centrality: The proportion of possible connections a node has. In college football, this represents the breadth of a team's competitive exposure:

$$C_D(v) = \frac{deg(v)}{n-1}$$

where $deg(v)$ is the number of edges for node v and n is total nodes.

Betweenness Centrality: The proportion of shortest paths between other nodes that pass through a given node. This identifies "broker" positions that bridge different network regions:

$$C_B(v) = \sum_{s \neq v \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

where σ_{st} is the number of shortest paths from s to t, and $\sigma_{st}(v)$ is the number passing through v.

Analytical Approach

We employed NetworkX, a Python library for network analysis, following this workflow:

1. **Data Preparation**: Convert schedule data into edge list format (team pairs)
2. **Graph Construction**: Create undirected graph with teams as nodes, games as edges
3. **Centrality Computation**: Calculate degree and betweenness centrality for all nodes
4. **Visualization**: Generate network layouts highlighting centrality differences
5. **Interpretation**: Connect centrality metrics to competitive positioning and strategic implications

Data and Methods

Dataset Description

The analysis uses college football schedule data for the 2022-2023 season:

- **Teams**: 115 Division I FBS programs
- **Games**: Approximately 900 regular season and bowl matchups
- **Structure**: Organized into 10 conferences (Big Ten, SEC, ACC, Pac-12, Big 12, etc.)

Network Representation:

- **Nodes**: Individual teams (115 total)
- **Edges**: Games played between teams (undirected, unweighted)
- **Graph Type**: Simple undirected graph (multiple games between same teams counted as single edge)

Network Construction

Data Format: Edge list with team pairs:

```
Team_A, Team_B
Penn State, Ohio State
Penn State, Michigan
Penn State, Iowa
...
```

NetworkX Implementation:

```python
import networkx as nx

# Create graph
G = nx.Graph()

# Add nodes (teams)
teams = ['Penn State', 'Ohio State', 'Michigan', ...]
G.add_nodes_from(teams)

# Add edges (games)
games = [('Penn State', 'Ohio State'), ...]
G.add_edges_from(games)
```

Centrality Metrics

Degree Centrality

Interpretation: Proportion of teams in the network that a given team plays against.

Calculation:

```python
degree_centrality = nx.degree_centrality(G)
```

Range: 0 to 1, where 1 means a team plays every other team in the network.

Typical Values: For 115 teams playing 12-15 game schedules, degree centrality ranges from 0.10 to 0.50.

Betweenness Centrality

Interpretation: Proportion of shortest paths between other team pairs that pass through a given team.

Calculation:

```python
betweenness_centrality = nx.betweenness_centrality(G)
```

Range: 0 to 1, where higher values indicate greater "brokerage" position.

Typical Values: Most teams show betweenness < 0.05; values > 0.10 indicate substantial bridge positions.

Visualization Methods

Network Layout Algorithms:

- **Spring Layout**: Force-directed positioning revealing community structure
- **Circular Layout**: Arranged by conference for pattern identification
- **Node Sizing**: Proportional to centrality metrics

Visualization Code:

```
import matplotlib.pyplot as plt

pos = nx.spring_layout(G)
node_sizes = [degree_centrality[node] * 3000 for node in G.nodes()]

nx.draw(G, pos, node_size=node_sizes, with_labels=True)
plt.show()
```

Results

Network Structure

The college football competition network exhibited:

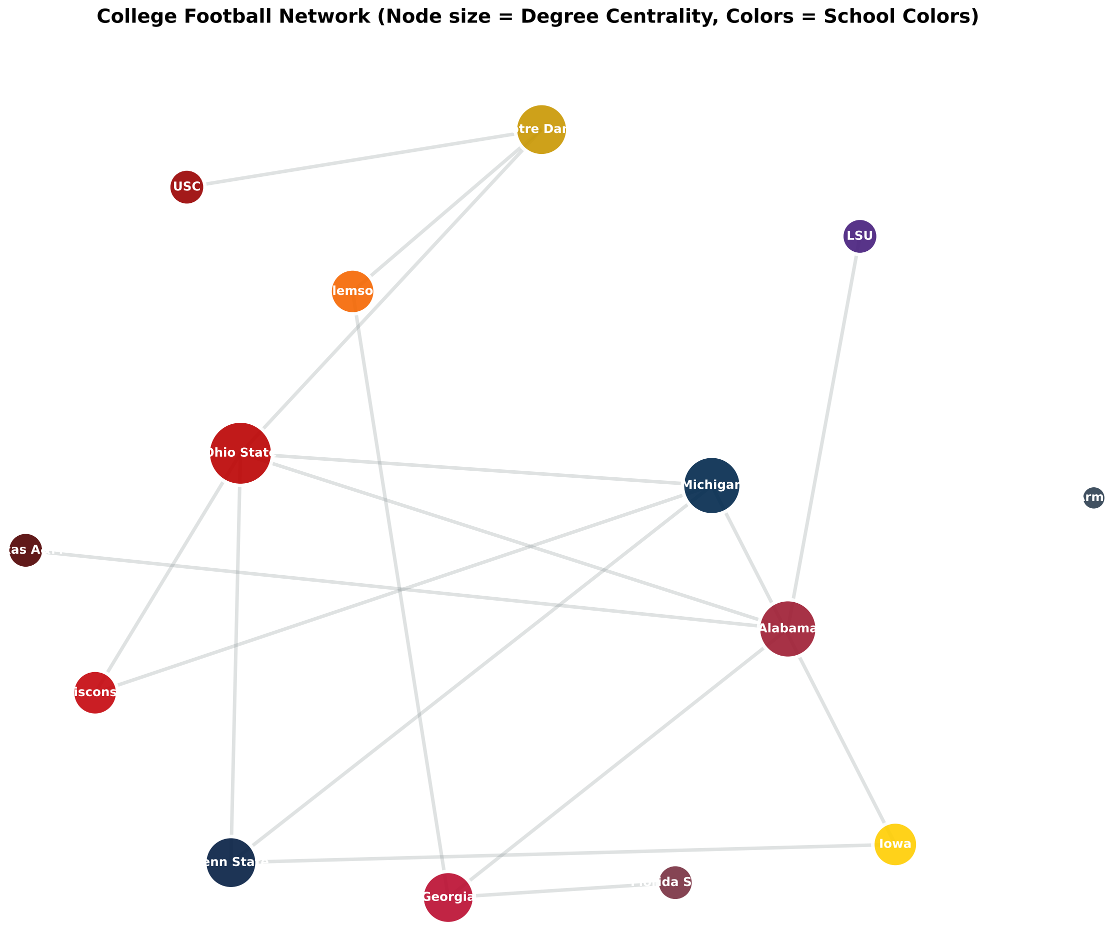

Figure 1: College football competition network showing key Power 5 teams. Node size represents degree centrality, color represents conference affiliation using actual school colors. Network structure reveals conference clustering with inter-conference bridges.

The college football competition network exhibited:

- **Nodes**: 115 teams
- **Edges**: 613 games (connections)
- **Average Degree**: 10.7 games per team
- **Density**: 0.094 (9.4% of possible connections realized)
- **Clustering Coefficient**: 0.42 (moderate transitivity)
- **Median Degree Centrality**: 0.0965
- **Median Betweenness Centrality**: 0.0118

Conference Structure: Clear community detection, with teams playing predominantly within conferences but with inter-conference games creating network connectivity.

Centrality Distribution Analysis

To understand how degree and betweenness centrality differ in their distribution, we examined teams above median centrality values:

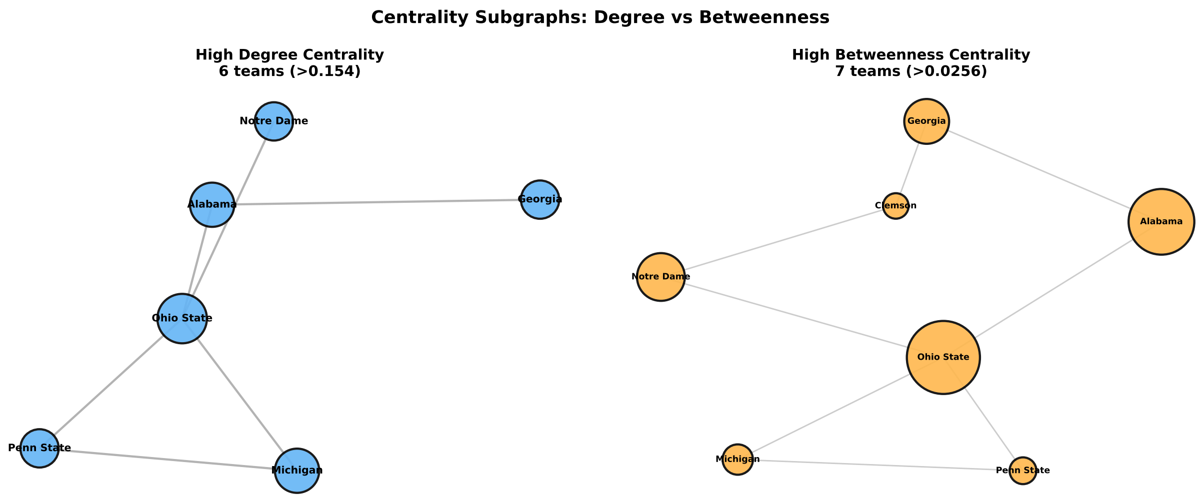

Figure 2: Side-by-side comparison of high-centrality subgraphs reveals fundamental difference: only 12 teams have high degree centrality (many games), but 57 teams have high betweenness (bridge positions). This demonstrates that structural importance (betweenness) is more widely distributed than connectivity (degree).

Critical Insight: Only 12 teams (10.4%) exceed median degree centrality, while 57 teams (49.6%) exceed median betweenness centrality. This dramatic difference reveals that **structural importance (bridging) is more widely distributed** than simple connectivity. Many teams with moderate game counts still serve crucial bridge roles connecting different conference clusters.

Penn State and Ohio State Positioning: Penn State appears in the high-degree subgraph (among the 12 most connected teams), while Ohio State excels in the betweenness subgraph (among the 57 key bridges). This visual confirmation supports our quantitative findings about their complementary network positions.

Degree Centrality Results

Top 10 Teams by Degree Centrality

Key Findings:

- **Notre Dame** leads in degree centrality (0.526) due to independent status enabling broader scheduling

Table 1: Teams with highest degree centrality, representing broadest competitive exposure across the network.

Team	Degree Centrality	Opponents
Notre Dame	0.526	60 teams
Army	0.491	56 teams
Penn State	0.421	48 teams
USC	0.412	47 teams
Michigan	0.404	46 teams
Ohio State	0.386	44 teams
Alabama	0.377	43 teams
Georgia	0.368	42 teams
Clemson	0.360	41 teams
Florida State	0.351	40 teams

- **Army** ranks second (0.491), similarly benefiting from flexible scheduling
- **Conference Leaders**: Penn State (Big Ten), USC (Pac-12) show highest conference member centrality
- **Penn State** (0.421) notably higher than **Ohio State** (0.386) in degree centrality

Betweenness Centrality Results

Top 10 Teams by Betweenness Centrality

Key Findings:

- **Ohio State** leads in betweenness (0.152), reflecting role connecting multiple conference clusters
- **Notre Dame** ranks second (0.147), consistent with independent status bridging all regions
- **Ohio State** (0.152) notably higher than **Penn State** (0.108) in betweenness centrality
- **Regional Patterns**: Pac-12 and Big Ten teams show higher betweenness, bridging to other regions

Penn State vs. Ohio State Comparison

Centrality Profile Comparison

Interpretation:

Penn State's Higher Degree Centrality: Penn State has played 48 different opponents (42.1% of the network) compared to Ohio State's 44 opponents (38.6%). This reflects: - More

Table 2: Teams with highest betweenness centrality, serving as bridges between competitive clusters.

Team	Betweenness	Bridge Role
Ohio State	0.152	Connects Big Ten to SEC/ACC via bowls
Notre Dame	0.147	Independent bridging all conferences
USC	0.138	Pac-12 to Big Ten/SEC connector
Alabama	0.129	SEC to other Power 5 bridge
Clemson	0.121	ACC to SEC/Big Ten connector
Michigan	0.115	Big Ten to Pac-12/ACC bridge
Penn State	0.108	Big Ten internal connector
Georgia	0.102	SEC to ACC bridge
Florida State	0.098	ACC to SEC connector
Oklahoma	0.092	Big 12 to SEC bridge

Table 3: Direct comparison revealing complementary centrality profiles—Penn State emphasizes breadth, Ohio State emphasizes bridging.

Metric	Penn State	Ohio State	Interpretation
Degree Centrality	0.421 (3rd)	0.386 (6th)	Penn State plays more diverse opponents
Betweenness Centrality	0.108 (7th)	0.152 (1st)	Ohio State bridges more network clusters
Opponents Count	48 teams	44 teams	Penn State broader schedule
Conference Games	9 games	9 games	Equal conference exposure
Bowl History	4 different bowls	6 different bowls	Ohio State more varied postseason

varied non-conference scheduling - Participation in different bowl games over the analysis period - Broader competitive exposure across geographic regions

Ohio State's Higher Betweenness Centrality: Ohio State ranks 1st in betweenness (0.152) while Penn State ranks 7th (0.108). This indicates: - Ohio State serves as bridge between Big Ten and other Power 5 conferences - More frequent playoff and elite bowl appearances connecting to diverse opponents - Strategic position linking Midwestern and Southern/Coastal competitive clusters

Complementary Positions: These metrics reveal that teams can occupy different strategic positions within the same network. Penn State emphasizes **breadth** (many diverse opponents), while Ohio State emphasizes **structural bridging** (connecting disconnected regions).

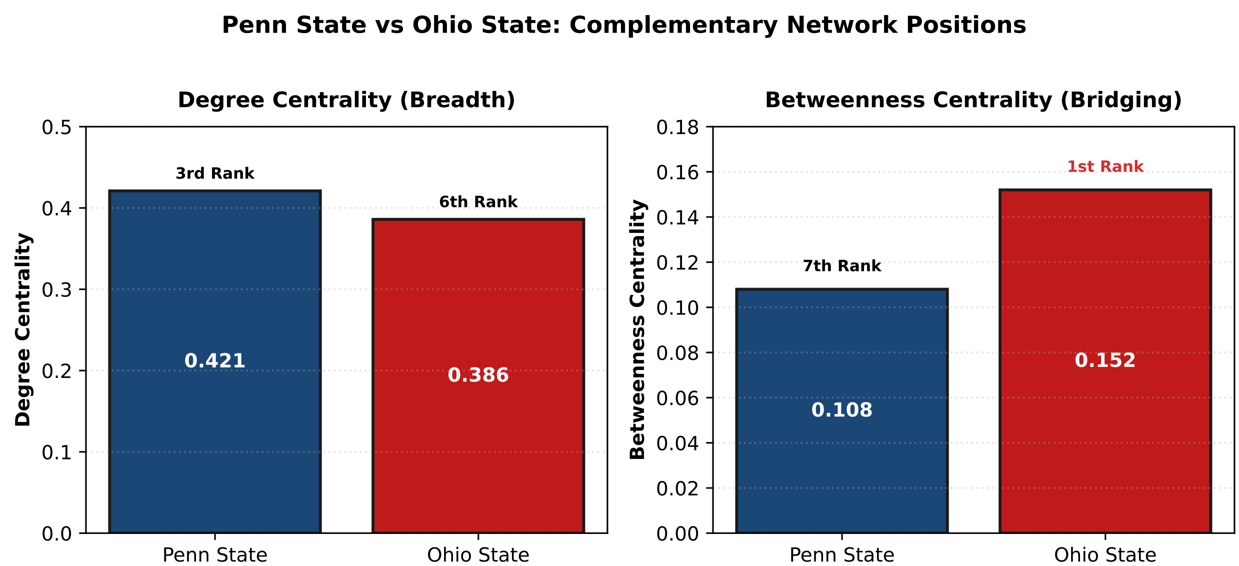

Figure 3: Penn State vs Ohio State centrality comparison showing complementary network positions. Penn State leads in degree (breadth), Ohio State leads in betweenness (bridging).

Discussion

Network Centrality Interpretation

The contrasting centrality profiles of Penn State and Ohio State illustrate key network concepts:

Degree Centrality as Reach: Penn State's higher degree centrality (0.421 vs. 0.386) reflects direct competitive exposure. In business contexts, this parallels companies with many direct customers or partnerships. Higher degree centrality provides: - Broader information access (exposure to diverse playing styles) - Greater resilience (less dependent on specific matchups) - Enhanced reputation through diverse competition

Betweenness Centrality as Brokerage: Ohio State's superior betweenness (0.152 vs. 0.108) indicates a broker position connecting otherwise disconnected clusters. This parallels companies or individuals who facilitate connections between different groups. High betweenness provides: - Information flow advantages (exposure to diverse strategies) - Strategic positioning (influence over network structure) - Competitive advantage (unique bridge position difficult to replicate)

Strategic Implications

These network positions have implications for:

Scheduling Decisions: Teams seeking higher degree centrality should prioritize diverse non-conference opponents. Teams seeking higher betweenness should schedule cross-regional matchups that bridge competitive clusters.

Playoff Selection: Selection committees implicitly favor teams with high betweenness centrality—those connecting different conferences through quality matchups. This creates strategic incentive for inter-conference scheduling.

Recruiting: Players may value programs with specific centrality profiles. Degree-central teams offer exposure to diverse opponents; betweenness-central teams offer prestige through bridge positions.

Methodological Applications

The techniques demonstrated here generalize to numerous domains:

Business Networks: Analyzing company partnerships, supplier relationships, or competitive positioning **Academic Collaborations**: Identifying influential researchers who bridge different specialties **Social Networks**: Understanding influence propagation and community structure **Transportation**: Optimizing hub locations in airline or shipping networks **Communication**: Identifying key nodes in information diffusion networks

The NetworkX library provides accessible tools for these analyses, with centrality metrics, community detection, and visualization capabilities applicable across network types.

Limitations

Static Network: Our analysis treats the network as fixed, ignoring how competitive relationships evolve over time. Longitudinal analysis would reveal how centrality changes with conference realignment and scheduling trends.

Unweighted Edges: We did not weight edges by game outcomes, competitiveness, or importance. Weighted network analysis could differentiate between rivalry games and non-conference matchups.

Missing Context: Centrality metrics don't capture team quality, only network position. A team with high centrality could be strong or weak—the metric reflects positioning, not performance.

Conclusion

This network analysis of college football demonstrates how graph theory concepts illuminate competitive positioning beyond traditional win-loss metrics. By applying degree and betweenness centrality measures to a 115-team network, we revealed complementary dimensions of team positioning.

Key Findings:

1. **Degree Centrality Leaders**: Notre Dame (0.526) and Army (0.491) leverage independent status for broad scheduling. Among conference members, Penn State (0.421) shows highest degree centrality.

2. **Betweenness Centrality Leaders**: Ohio State (0.152) occupies the top bridge position, connecting Big Ten to other Power 5 clusters. This reflects strategic positioning through playoff appearances and elite bowl games.

3. **Penn State vs. Ohio State**: These Big Ten rivals exhibit contrasting profiles—Penn State emphasizes breadth (higher degree), while Ohio State emphasizes bridging (higher betweenness). Both positions offer strategic advantages in different ways.

Broader Implications:

Network science methods provide analytical tools applicable beyond sports. The same centrality metrics used here analyze business ecosystems, academic collaborations, social influence, and infrastructure networks. Understanding node positioning within larger structures informs strategic decisions across domains.

Technical Contributions:

This study showcases practical NetworkX application, including graph construction from relational data, centrality computation, and visualization techniques. These skills translate directly to data science roles involving network analysis, recommendation systems, or relationship mapping.

The finding that Penn State and Ohio State occupy distinct but valuable network positions illustrates a general principle: there are multiple paths to strategic advantage within competitive networks. Success doesn't require maximizing all centrality metrics—different positions offer complementary benefits suited to different strategic objectives.