The Optimal NBA Roster-Building Strategy

Patrick Simpson Dr. Max Buot

Xavier University

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Outline

1. What is Cluster Analysis?

2. Applying the Agglomerative Clustering Algorithm

3. Applying Hierarchical Clustering to NBA Data

Background

- Clustering is in our everyday life
- Cluster analysis methodology
- Early uses

Hierarchical Clustering

- Two different approaches:
    - Agglomerative
    - Divisive

Agglomerative Hierarchical Clustering Algorithm

Algorithm Agglomerative Clustering Algorithm

```
1: Starting with a dataset of $N$ observations, each begins in its own cluster.
   Form an $N \times N$ proximity matrix.
2: Identify the two most similar clusters.
3: Merge those clusters and recompute the proximity matrix (Note: it will
   have one fewer row and column than the previous matrix).
4: Repeat steps (2) and (3) until the proximity matrix is $1x1$.
```

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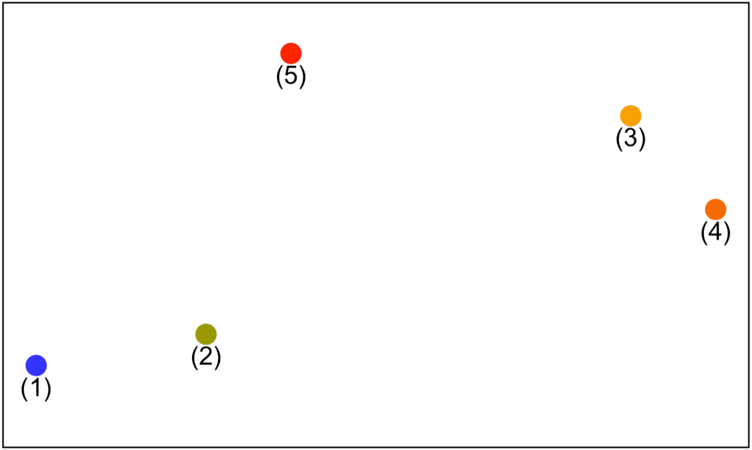
Sample Data



Step I

Algorithm Agglomerative Clustering Algorithm

```
1: **Starting with a dataset of $N$ observations, each begins in its own cluster. Form an $N$x$N$ proximity matrix.**
2: Identify the two most similar clusters.
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```

Creating the Proximity Matrix

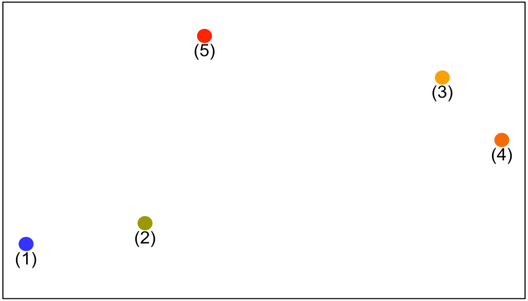
There are different measures of distance between two objects; in this model Euclidean Distance is used.

Definition

Let x and y be two points. The Euclidean Distance function between x and y can be expressed as: $d_{euc}(x, y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$

Proximity Matrix

	1	2	3	4	5
1	$\underline{\mathbf{0}}$	2.24	10.63	9.43	10.44
2	2.24	$\underline{\mathbf{0}}$	8.60	7.21	9.06
3	10.63	8.60	$\underline{\mathbf{0}}$	3.16	4.47
4	9.43	7.21	3.16	$\underline{\mathbf{0}}$	7.07
5	10.44	9.06	4.47	7.07	$\underline{\mathbf{0}}$



Step II

Algorithm Agglomerative Clustering Algorithm

```
1: Starting with a dataset of $N$ observations, each begins in its own cluster.
   Form an $N$×$N$ proximity matrix.
2: Identify the two most similar clusters.
3: Merge those clusters and recompute the proximity matrix (Note: it will
   have one fewer row and column than the previous matrix).
4: Repeat steps (2) and (3) until the proximity matrix is 1$x$1.
```

Merging the Two Most Similar Clusters

	1	2	3	4	5
1	**0**	2.24	10.63	9.43	10.44
2	2.24	**0**	8.60	7.21	9.06
3	10.63	8.60	**0**	3.16	4.47
4	9.43	7.21	3.16	**0**	7.07
5	10.44	9.06	4.47	7.07	**0**

Step III

Algorithm Agglomerative Clustering Algorithm

```
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4: Repeat steps (2) and (3) until the proximity matrix is $1x1$.
```

Recomputing the Proximity Matrix

	12	3	4	5
12	**0**			
3		**0**	3.16	4.47
4		3.16	**0**	7.07
5		4.47	7.07	**0**

How do we account for a multi-observational cluster?

Measure of Dissimilarity

- Complete Linkage

Definition

Let G and H represent two clusters. The dissimilarity $d(G,H)$ between G and H is computed from the set of pairwise observation dissimilarities ij where one member of the pair i is in G and the other j is in H. The dissimilarity of G and H with complete linkage is computed as follows:

$$d_{CL}(G, H) = \max_{i \in G, j \in H} d_{ij}$$

- Average Linkage
- Single Linkage

Recomputing the Proximity Matrix (cont.)

	12	3	4	5
12	**0**			
3		**0**	3.16	4.47
4		3.16	**0**	7.07
5		4.47	7.07	**0**

$$d_{CL}(12,3) = \max_{i \in G, j \in H} d_{ij}$$

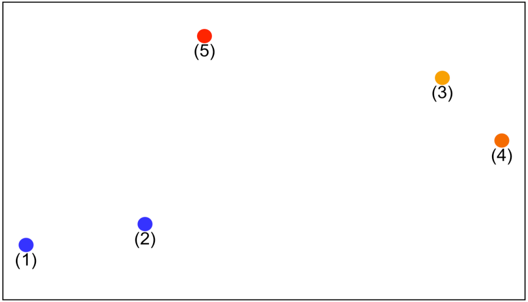
$$d_{CL}(12,3) = \max(d_{euc}(13), d_{euc}(23))$$

$$d_{CL}(12,3) = \max(10.63, 8.60)$$

$$d_{CL}(12,3) = 10.63$$

Updated Proximity Matrix

	12	3	4	5
12	**0**	10.63	9.43	10.44
3	10.63	**0**	3.16	4.47
4	9.43	3.16	**0**	7.07
5	10.44	4.47	7.07	**0**



Step IV

Algorithm Agglomerative Clustering Algorithm

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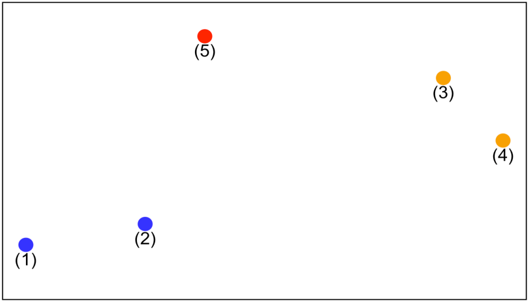
4: **Repeat steps (2) and (3) until the proximity matrix is $1x1$.**
```

Applying the Algorithm

	12	3	4	5
12	**0**	10.63	9.43	10.44
3	10.63	**0**	3.16	4.47
4	9.43	3.16	**0**	7.07
5	10.44	4.47	7.07	**0**

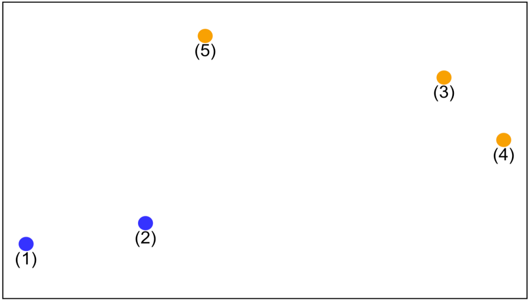
Applying the Algorithm (Cont.)

	12	34	5
12	**0**	10.63	10.44
34	10.63	**0**	4.47
5	10.44	4.47	**0**



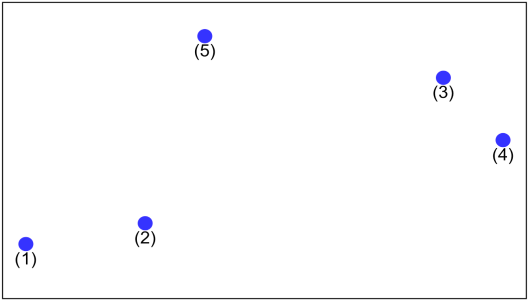
Applying the Algorithm (Cont.)

	12	345
12	**0**	10.63
345	10.63	**0**

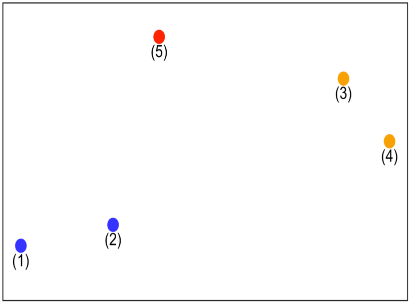


Applying the Algorithm (Cont.)

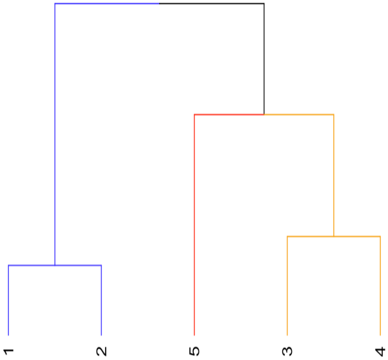
	12345
12345	0



Visualizing the Hierarchical Relationship



Observations



Dendrogram

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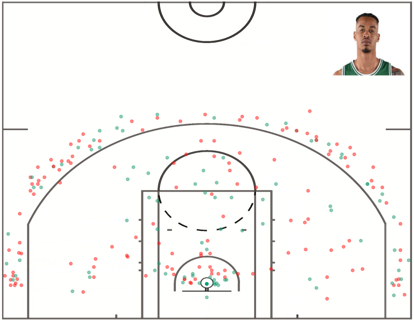
NBA Clustering

- Goal
  - To cluster players into archetypes based on skillsets

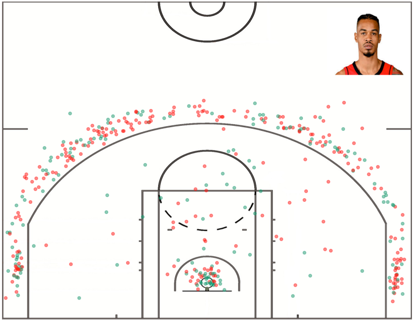
- Challenges
  - Must use player performance to determine ability. These are not the same.
  - Accounting for variables such as team philosophy, role in offense, level of teammates, etc.

Challenges (cont.)

It is unlikely Gerald Green's shooting ability improved in year 13.



Boston 2016-17 (47 gp)



Houston 2017-18 (41 gp)

The Data

- Data was collected via NBA.com, synergy sports, pbpbasketball.com, basketball-reference.com, and fivethirtyeight.com by scraping the sites.

- Tracking data did not become available until the 2013-14 season, so I only focused on the past 5 seasons.

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Player	Avg. Sec Per Touch	Avg. Dribble Per Touch	Pts. Per Touch
LeBron James	4.52	3.32	0.32
Stephen Curry	3.73	3.45	0.36
James Harden	6.37	5.92	0.41

Table: 2018-19 Per Second Spectrum

Proximity Matrix

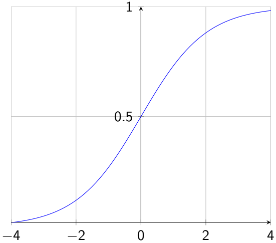
- For each season, an 8 component vector was created for each player.
- The Components:
  1. **3PT Shooting**
  2. **Mid-Range Scoring**
  3. **Inside Scoring**
  4. **Roll Gravity** (how effective a player is in the pick-and-roll)
  5. **Playmaking** (ability to create shots for teammates)
  6. **Self-Creation** (ability to get own shot)
  7. **Rebounding**
  8. **Defense**

3PT Shooting Component (Unadjusted)

- Classified 3pt attempts as contested, open, or wide open based on defender distance.
- For each category, calculated the players *shooting ability over expectation* (SAOE).
- Ex: $(SAOE)_{open} =$ proportion of open attempts (fgp-expected fgp)
- Also considered the location of shot.
- $unadjustedshootingcomponent = \sum_{i \in A}(SAOE_i)$
  - A = (Tightly Contested, Open, Wide Open, ATB, Corner)

3PT Shooting Component (Adjusted)

- Normalized the number of 3 point field goal attempts for each player.
- Passed the normalized variable through a sigmoid function to obtain a value, r.
- Then $SAOE_{adjusted} = (r)\ SAOE_{unadjusted}$ (given $SAOE_{unadjusted} > 0$).



$$S(x) = \frac{e^x}{1+e^x}$$

Name	Season	FG3A	Component
Kyle Korver	2014-15	449	0.2637
JJ Redick	2015-16	413	0.2134
Stephen Curry	2015-16	884	0.2089
Joe Harris	2018-19	386	0.2059
Kyle Korver	2013-14	392	0.1972
Stephen Curry	2014-15	646	0.1931

2018-19 Hierarchical Clustering Results

- There were 423 players who played at least 15 games.
- I created 15 clusters (avg. 28 player per cluster)
- 5 clusters had an average VORP > 0.
  - **Superstars**
  - **Supporting Stars**
  - **2-way Bigs**
  - **Playmaking Defenders**
  - **3&D Wings**

Archetypes

Archetype	PPG	RPG	APG	AVG. SALARY
Superstars	23.6	7.1	5.0	24.5M
Supporting Stars	14.2	4.6	3.8	16.6M
2-Way Bigs	15.2	9.5	2.4	15.8M
Playmaking Defenders	8.0	3.9	2.1	7.3M
3&D Wings	10.5	2.9	2.6	7.4M

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Superstars: LeBron James, Kevin Durant, Kawhi Leonard

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Supporting Stars: Stephen Curry, Kyrie Irving, Kyle Lowry
2-Way Bigs: Joel Embiid, Anthony Davis, Rudy Gobert
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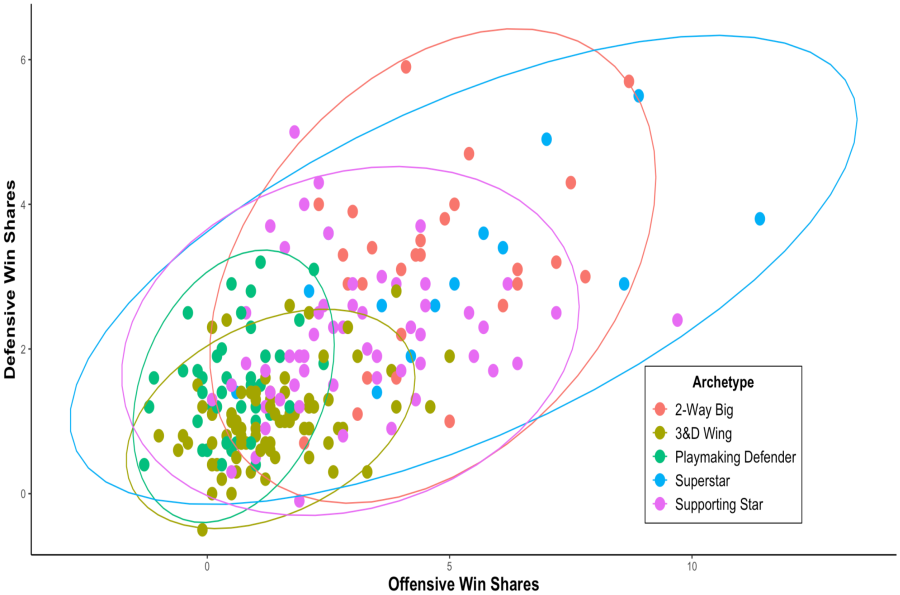
3&D Wings: Klay Thompson, Robert Covington, P.J. Tucker

2018-19 Hierarchical Clustering Results



Future Research

- Linking clusters by season
- Predicting which clusters rookies will belong to
- Modeling career trajectories

Thank You

- Thank you to everyone who helped and supported me during my four years at Xavier!