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SkyLens: Visual Analysis of Skyline on Multi-dimensional Data

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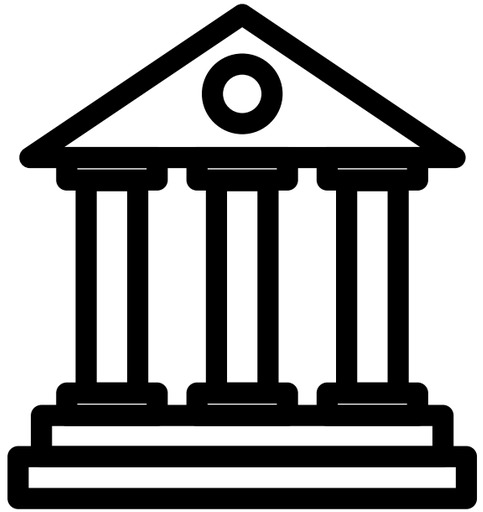
Microsoft Research
微软亚洲研究院

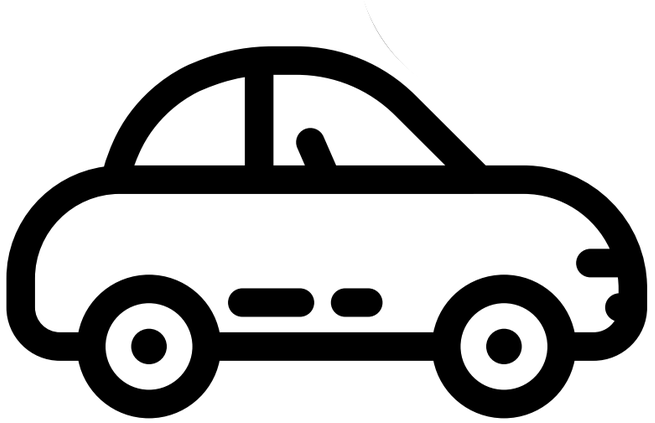
Background

- Multi-criteria decision making

Employee recruitment



University selection



Car comparison

Background

- Suppose you are a college basketball coach, how do you recruit the best players?

PLAYER	TEAM	AGE	GP	W	L	MIN	OFFRTG	DEFRTG	NETRTG	AST%	AST/TO	AST RATIO	OREB%
AJ Hammons	DAL	24	22	4	18	7.4	102.2	102.8	-0.6	3.8	0.40	6.2	4.9
Aaron Brooks	IND	32	65	36	29	13.7	101.5	104.6	-3.0	21.6	1.89	24.6	2.2
Aaron Gordon	ORL	21	80	29	51	28.7	105.4	108.2	-2.8	9.7	1.69	12.5	5.4
Aaron Harrison	CHA	22	5	2	3	3.3	83.3	101.9	-18.6	37.5	0.00	38.1	0.0
Adreian Payne	MIN	26	18	5	13	7.5	102.6	101.8	0.8	8.9	0.88	9.0	6.9
Al Horford	BOS	31	68	46	22	32.3	110.7	105.8	5.0	23.9	2.93	25.7	4.9
Al Jefferson	IND	32	66	33	33	14.1	102.3	108.1	-5.8	11.4	1.73	9.5	8.6
Al-Farouq Aminu	POR	26	61	33	28	29.1	107.7	105.9	1.8	8.2	1.05	13.8	4.9
Alan Anderson	LAC	34	30	20	10	10.3	103.1	114.0	-10.8	5.2	1.57	10.5	1.1
Alan Williams	PHX	24	47	11	36	15.1	105.6	105.8	-0.3	4.9	0.62	6.1	13.8
Alec Burks	UTA	25	42	26	16	15.5	105.0	104.9	0.1	7.4	0.86	8.6	2.9
Alex Abrines	OKC	23	68	37	31	15.5	106.0	108.3	-2.3	5.5	1.21	9.2	1.9
Alex Len	PHX	24	77	21	56	20.3	99.4	110.5	-11.1	4.3	0.43	6.3	10.4

Introduction – Skyline

- Skyline algorithm: automatically select the skyline of the dataset

- In database, skyline algorithm is an important and extensively studied problem

Introduction – Skyline

- Skyline algorithm: automatically select the skyline of the dataset

Introduction – Skyline Definition

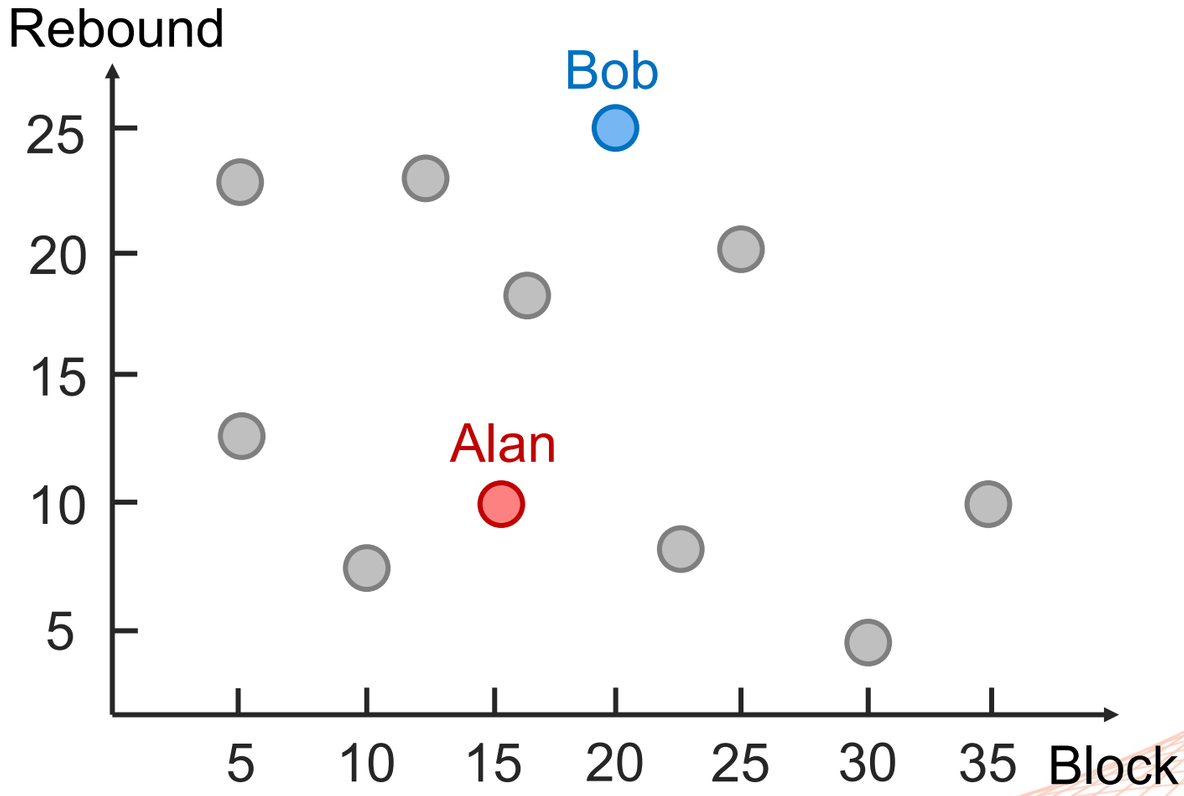
- Skyline: a set of superior points that are not dominated by other points in the dataset

- Dominance:
  - If *p* dominates *q*, then:
    - *p* is not worse than *q* in all attributes
    - *p* is at least better than *q* in one attribute

Introduction – Skyline Example

- Skyline: a set of superior points that are not dominated by other points in the dataset

Players	Block	Rebound
Alan	15	10
Bob	**20**	**25**

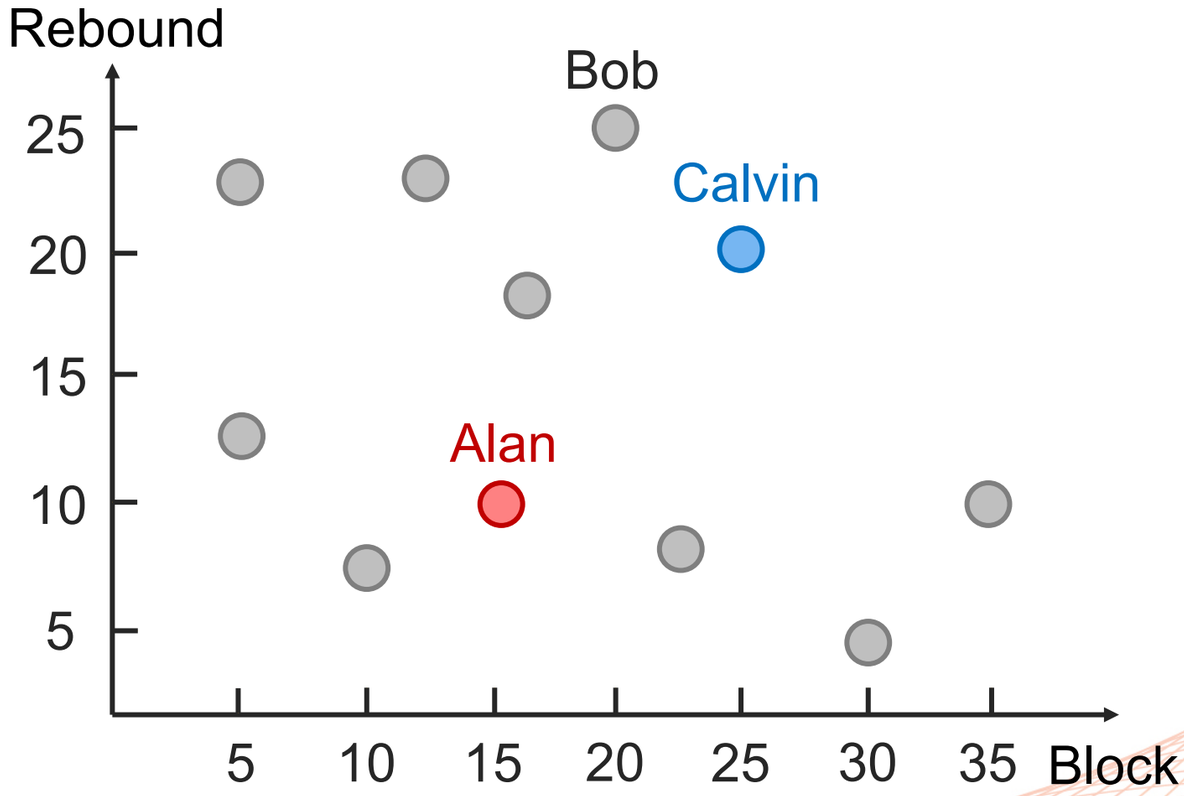


Bob dominates Alan (**block** & **rebound**)

Introduction – Skyline Example

- Skyline: a set of superior points that are not dominated by other points in the dataset

Players	Block	Rebound
Alan	15	10
Bob	20	25
Calvin	**25**	**20**



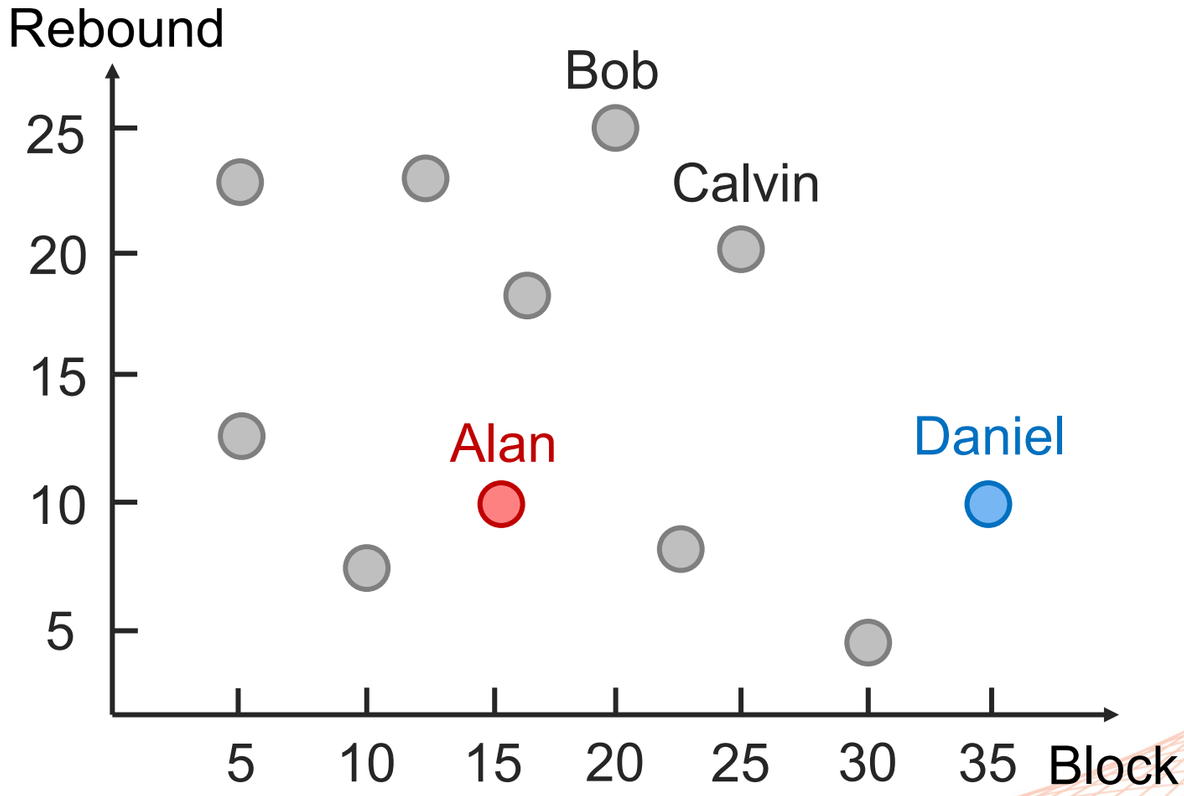
Calvin dominates Alan (**block** & **rebound**)

Introduction – Skyline Example

- Skyline: a set of superior points that are not dominated by other points in the dataset

Players	Block	Rebound
Alan	15	10
Bob	20	25
Calvin	25	20
Daniel	**30**	**10**

Daniel dominates Alan (**block**)

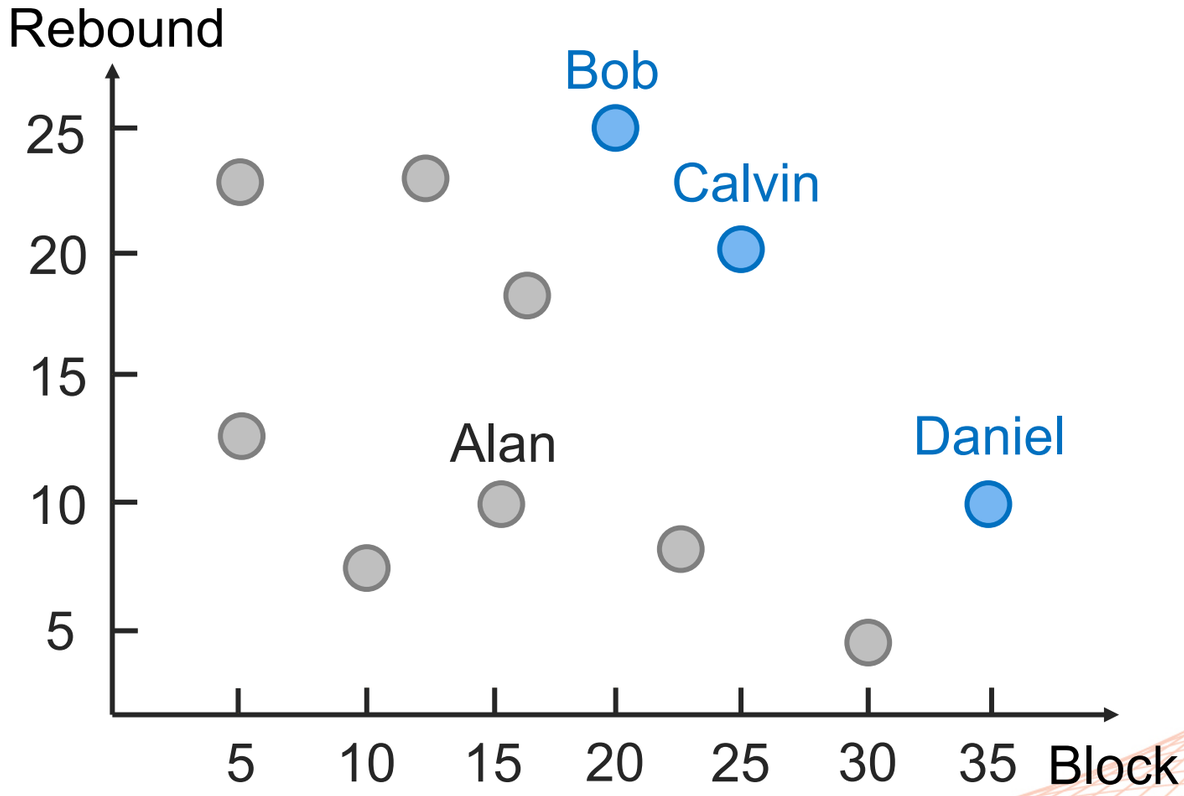


Introduction – Skyline Example

- Skyline: a set of superior points that are not dominated by other points in the dataset

Players	Block	Rebound
Alan	15	10
Bob	**20**	**25**
Calvin	**25**	**20**
Daniel	**30**	**10**

Points: Daniel > Calvin > Bob
Rebound: Bob > Calvin > Daniel

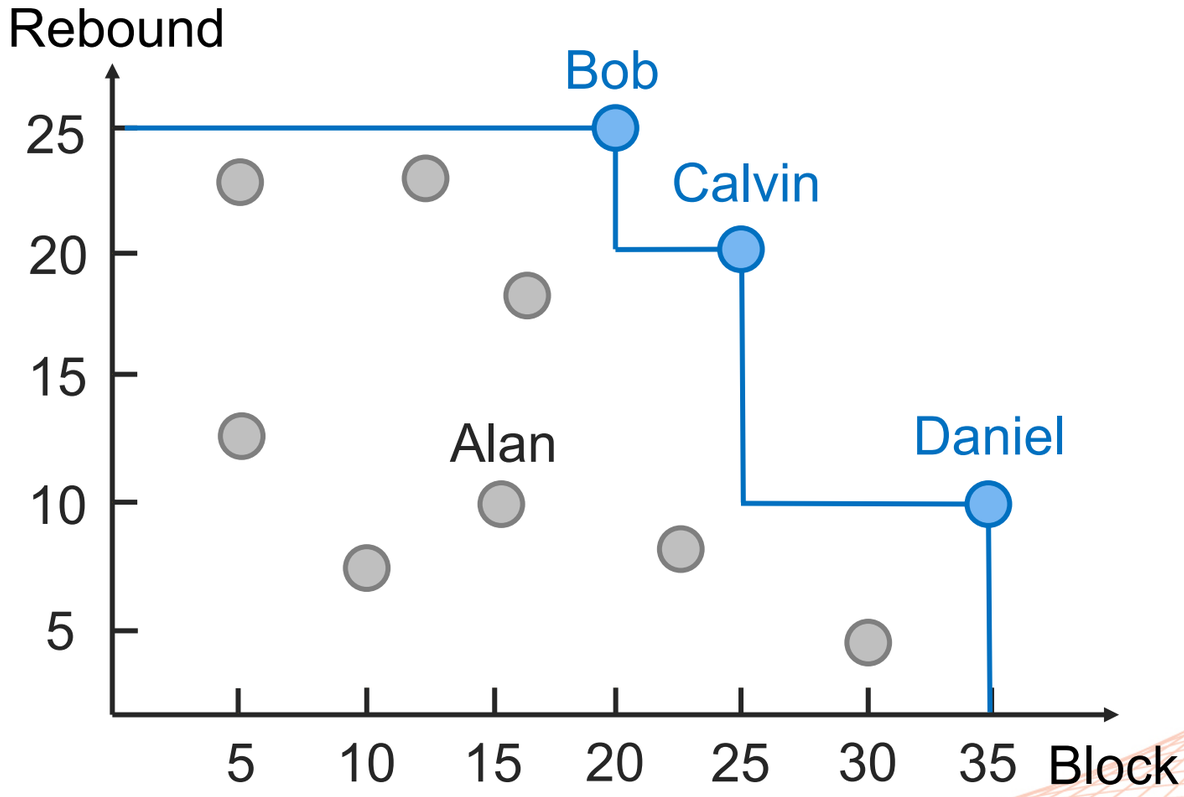


Introduction – Skyline Example

- Skyline: a set of superior points that are not dominated by other points in the dataset

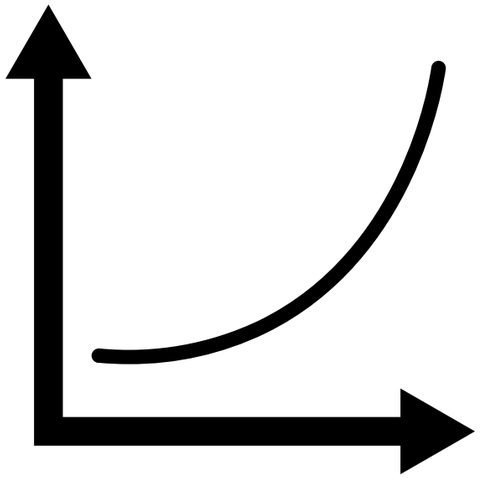
Players	Block	Rebound
Alan	15	10
Bob	**20**	**25**
Calvin	**25**	**20**
Daniel	**30**	**10**

Skyline: Bob, Calvin, Daniel



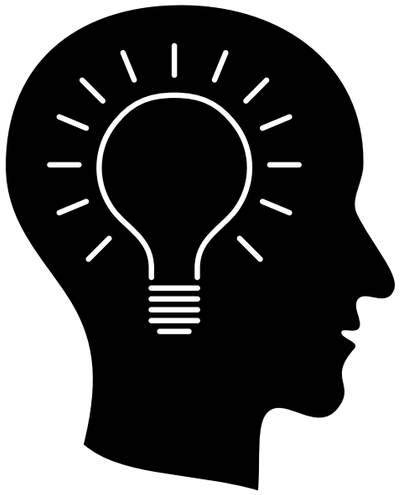
Introduction – Challenges

Scalability



The size of skyline increases with the number of attributes

Interpretation



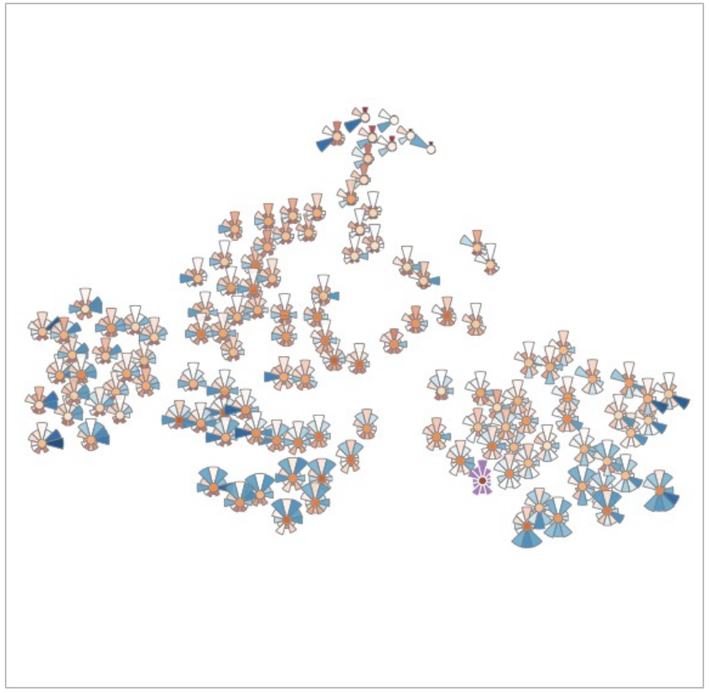
The reasons that make a point in skyline is unclear

Comparison

The strength and weakness of each skyline point is implicit

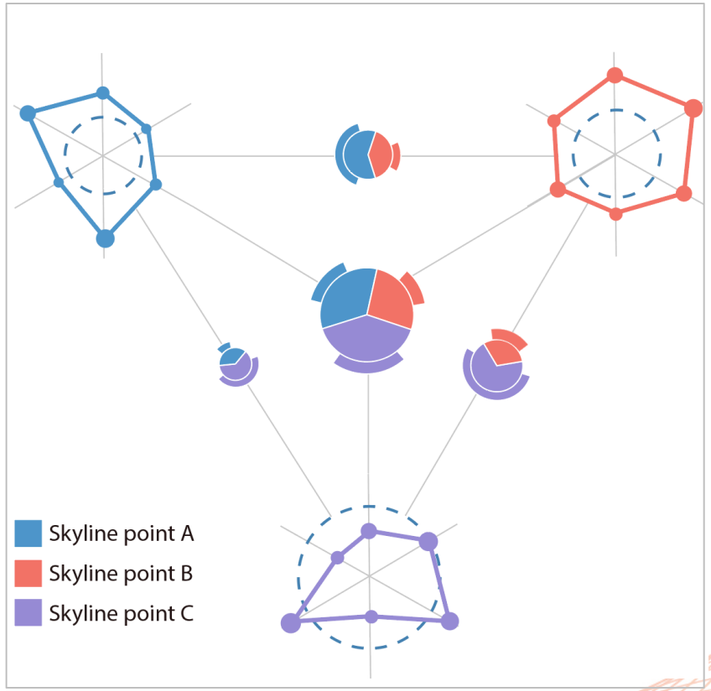
SkyLens – Visual Components

Projection View

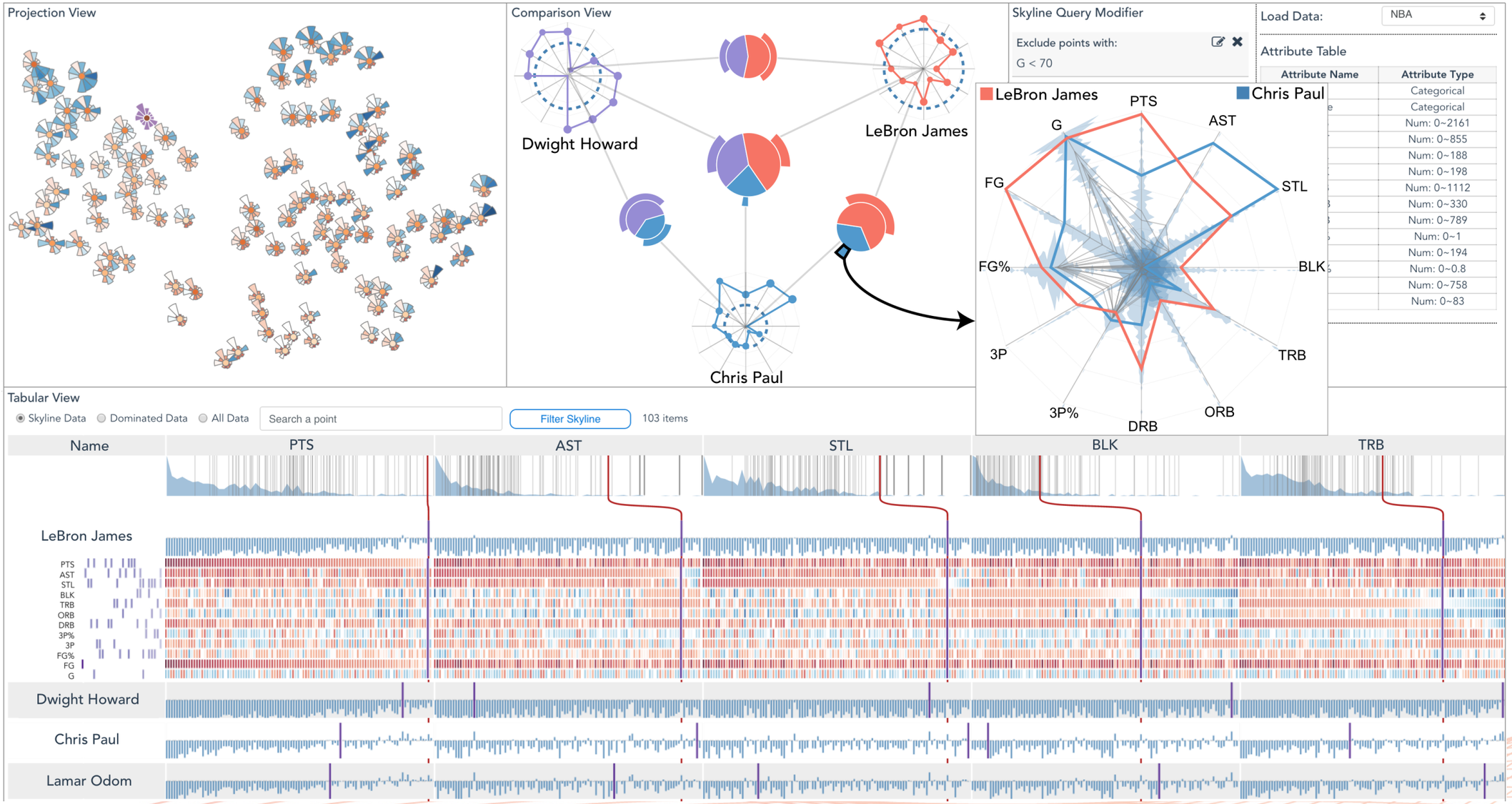


Tabular View

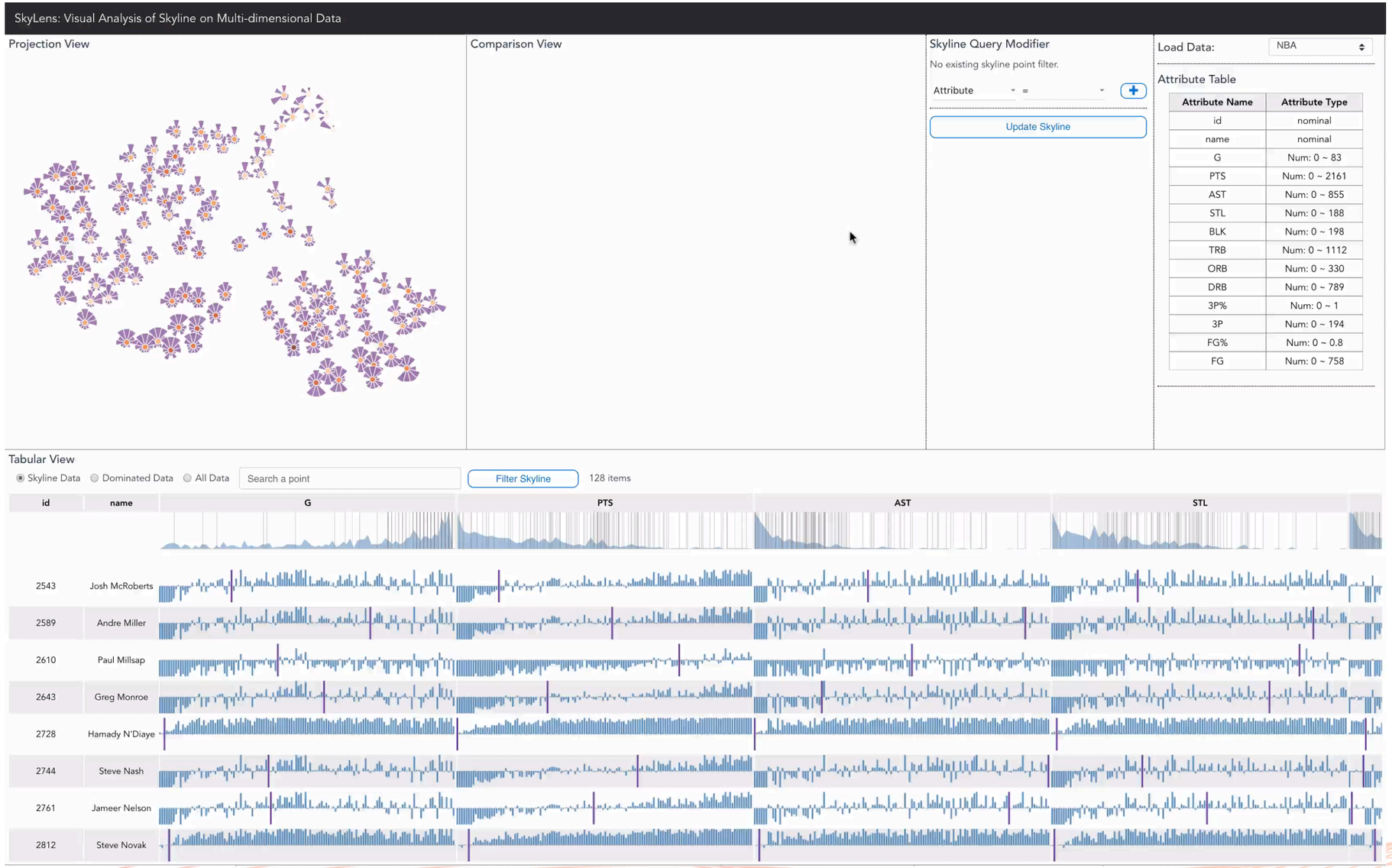
Comparison View



SkyLens – Demo!



SkyLens – Video

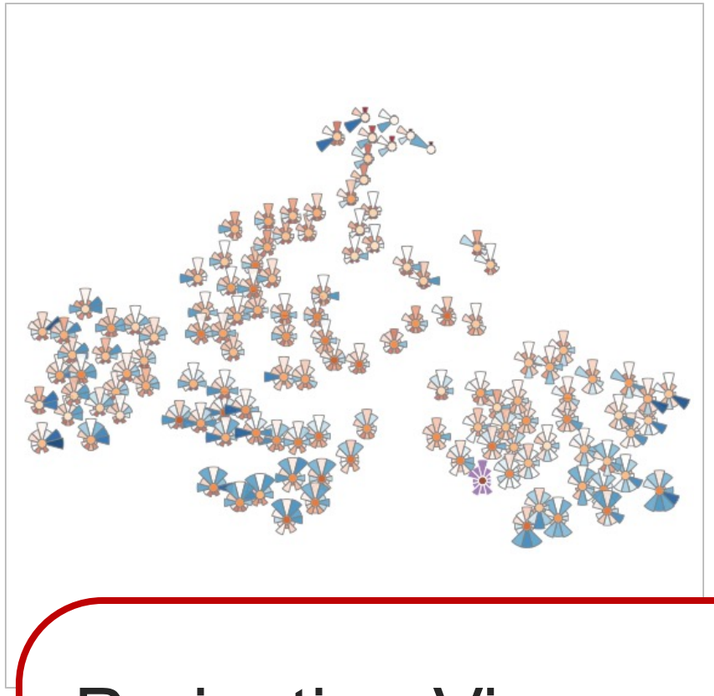


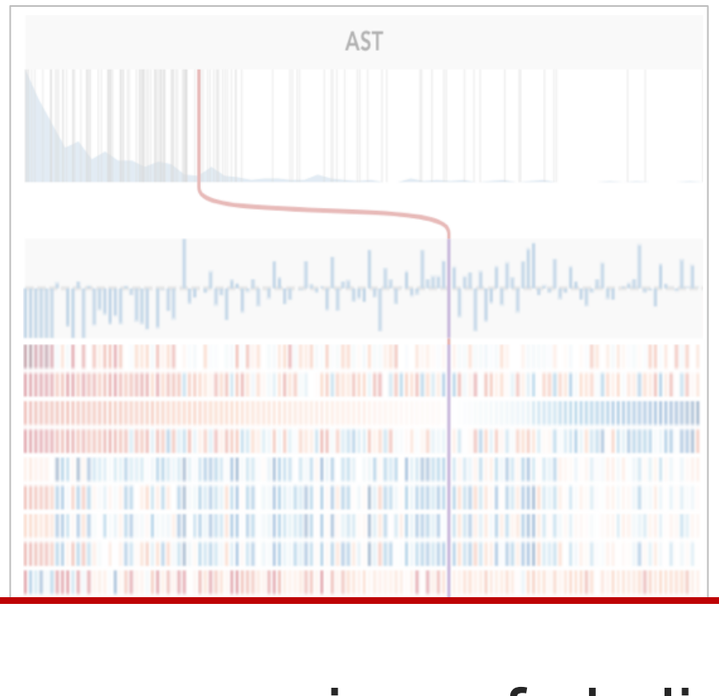
SkyLens – Projection View

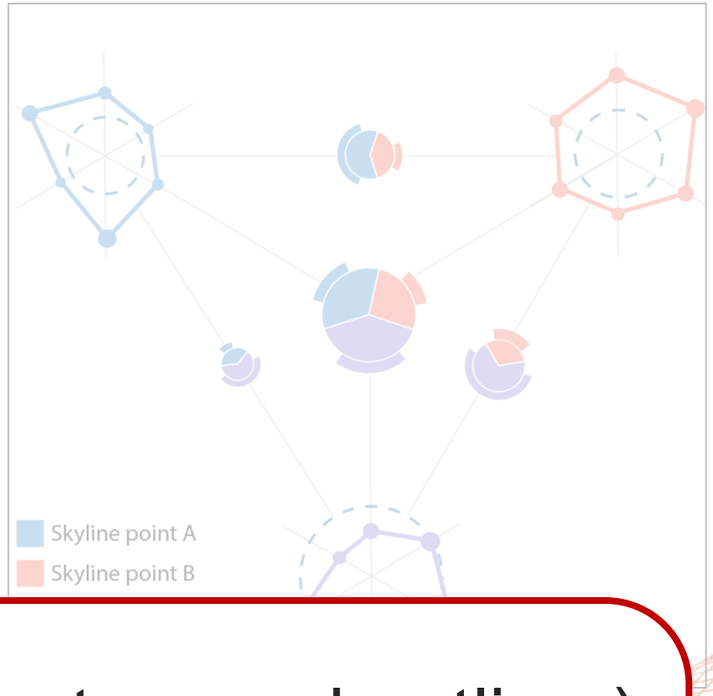
Projection View

Tabular View

Comparison View



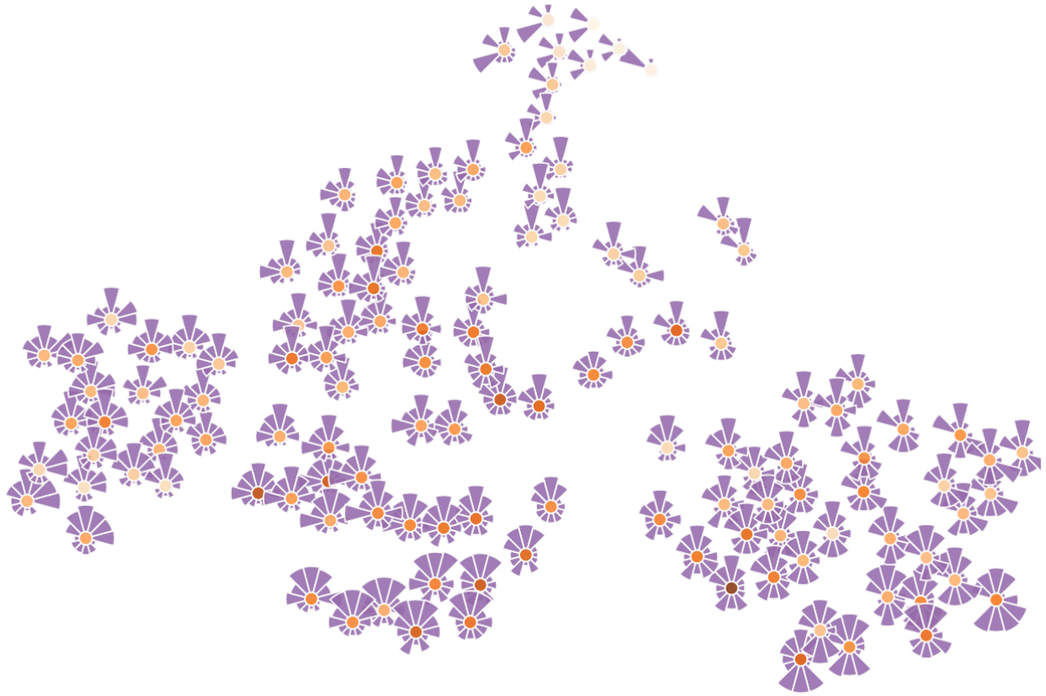




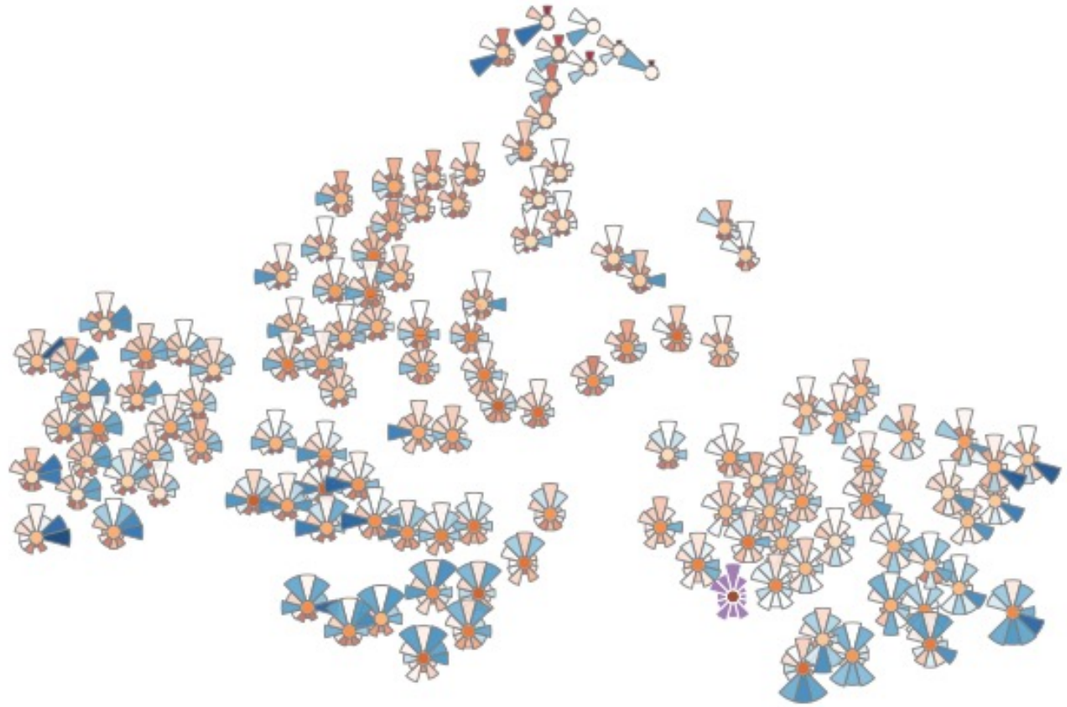
Projection View: provide an overview of skyline (clusters and outliers)

Projection View

- Methods: t-SNE projection and skyline glyphs



Normal mode

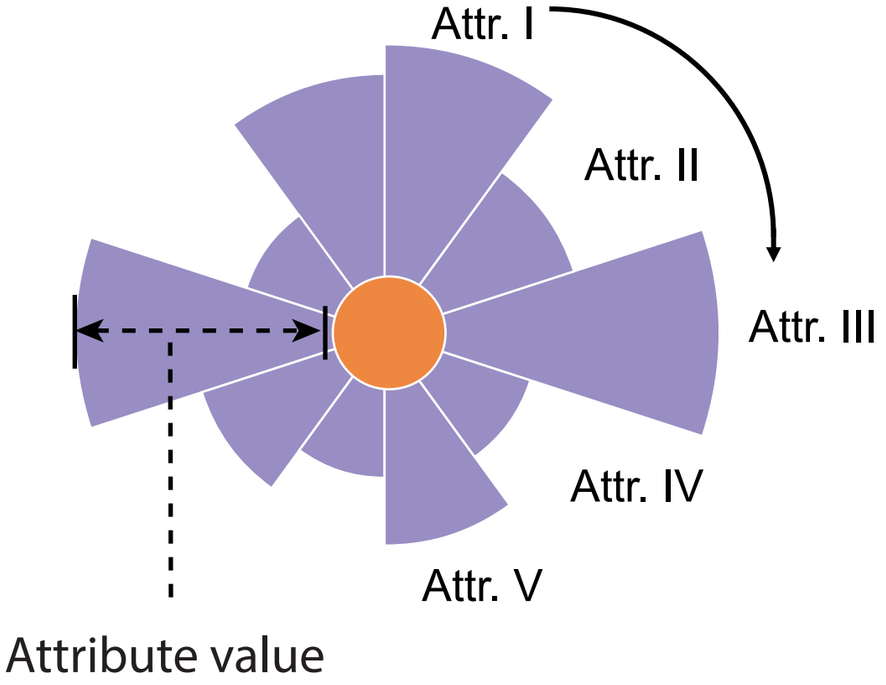


Focus mode

Projection View – Skyline Glyph

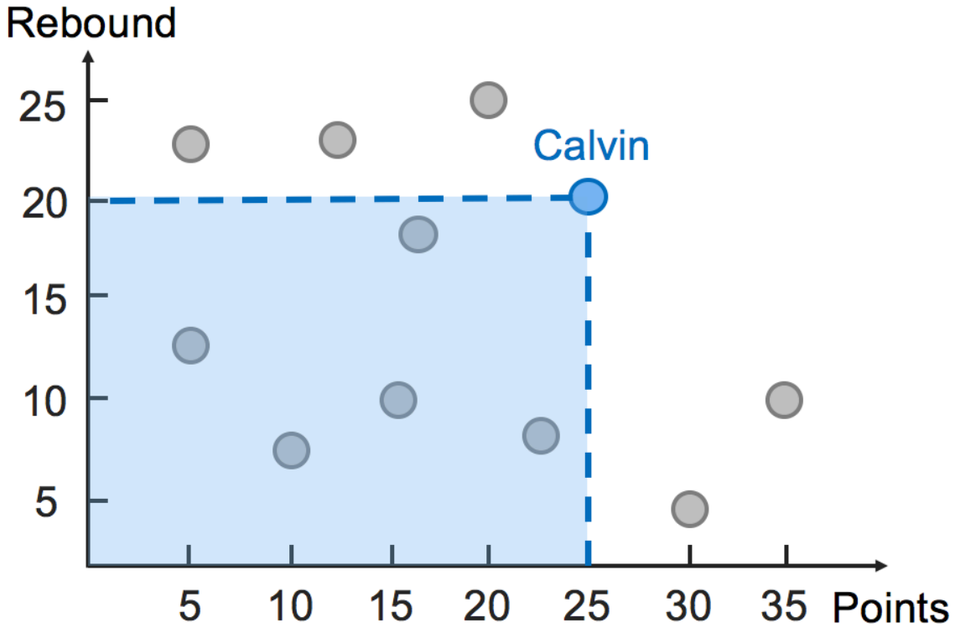
- Normal mode: show the attribute value distribution of skyline

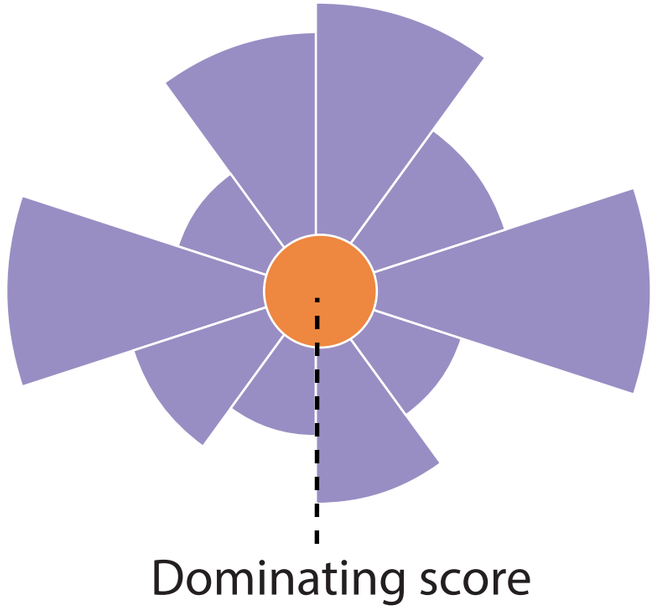
Attribute	Value
Attr. I	5
Attr II	3
Attr. III	7
Attr. IV	1
Attr. V	3
Attr. VI	1
…	

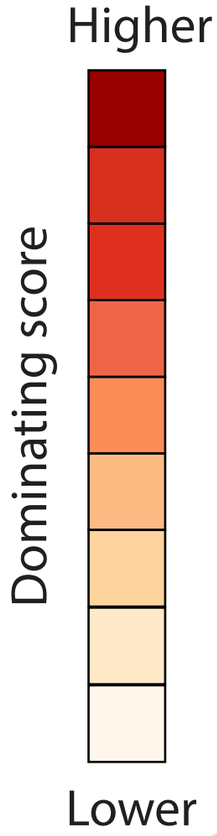


Projection View – Skyline Glyph

- Normal mode: show the attribute value distribution of skyline
- Dominating score (superiority metric):
  - # of points dominated by this point







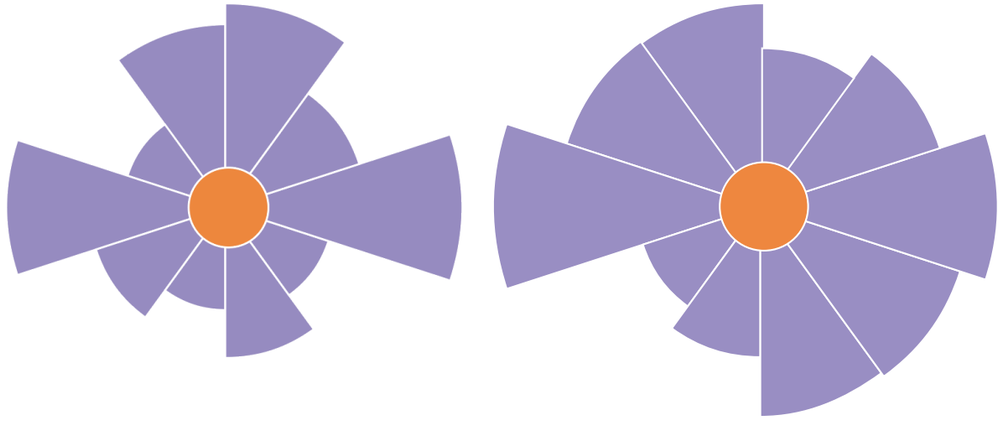
Projection View – Skyline Glyph

- Focus mode: highlight how other points differ from a focused one

Attribute	Point A	Point B
Attr. I	5	**3**
Attr II	3	**4**
Attr. III	7	**6**
Attr. IV	1	**5**
Attr. V	3	**5**
Attr. VI	1	**3**
…		

Point A
(focused point)

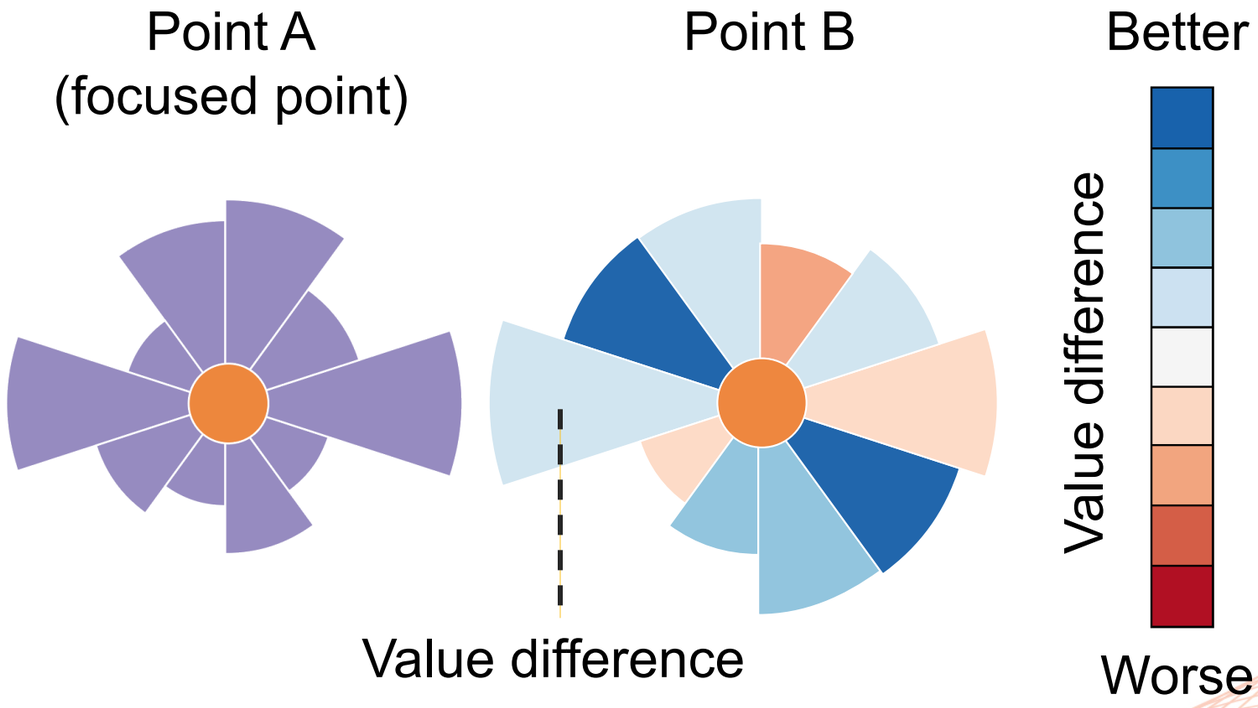
Point B



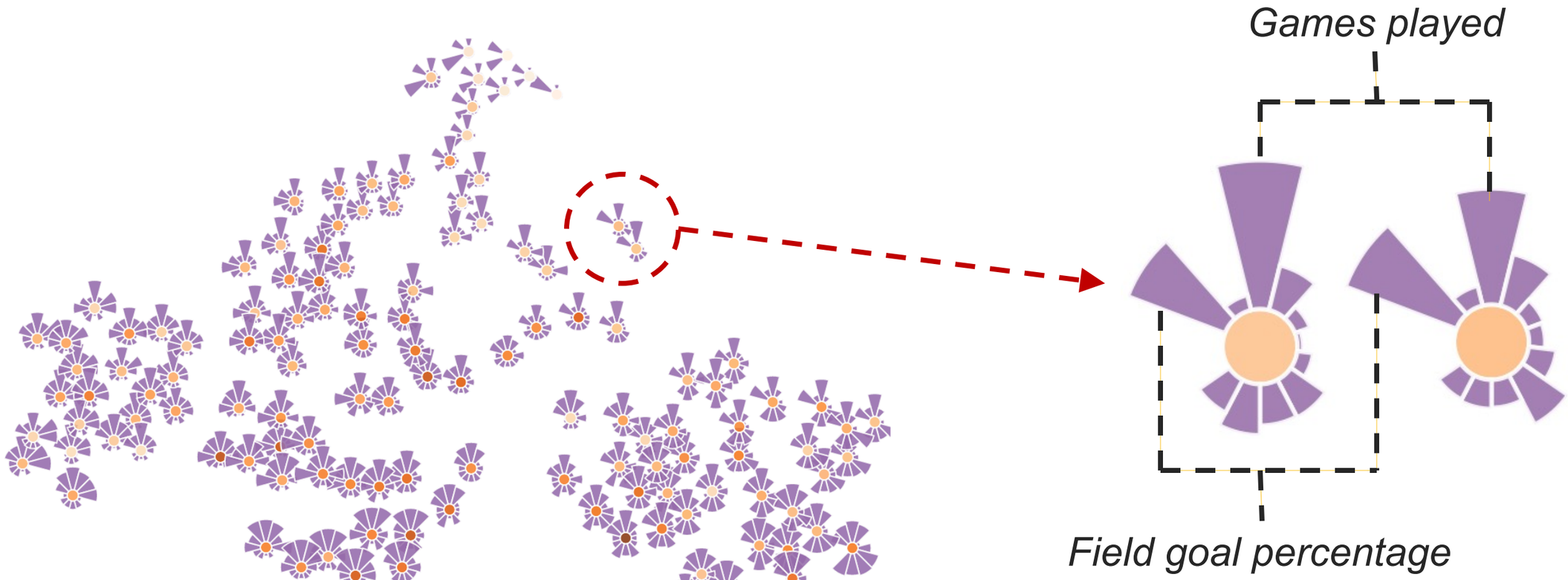
Projection View – Skyline Glyph

- Focus mode: highlight how other points differ from a focused one using color map

Attribute	Point A	Point B
Attr. I	5	**3 (diff. = -2)**
Attr II	3	**4 (diff. = 1)**
Attr. III	7	**6 (diff. = -1)**
Attr. IV	1	**5 (diff. = 4)**
Attr. V	3	**5 (diff. = 2)**
Attr. VI	1	**3 (diff. = 2)**
…		

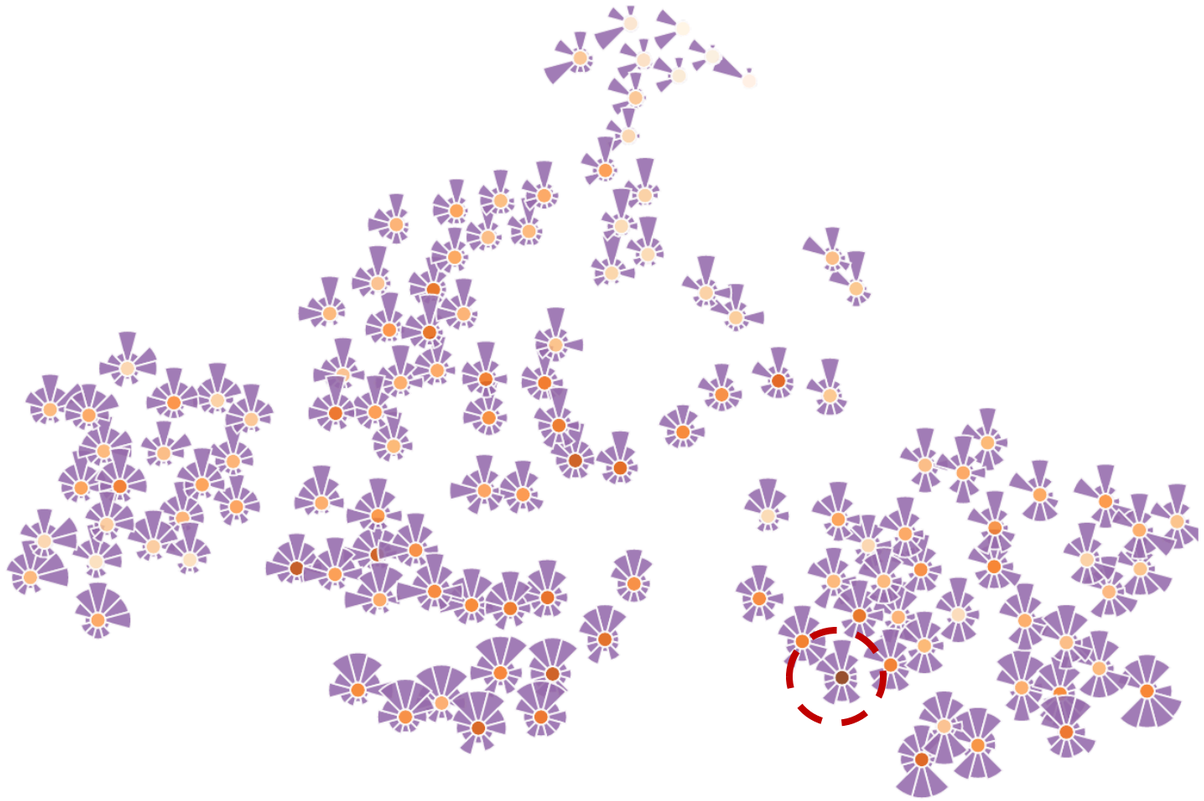


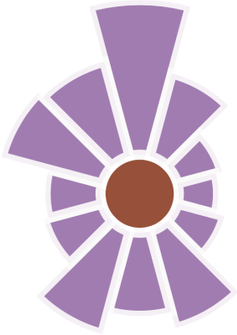
Projection View – Case Studies



Two outliers with high values on *games played* and *FG%*

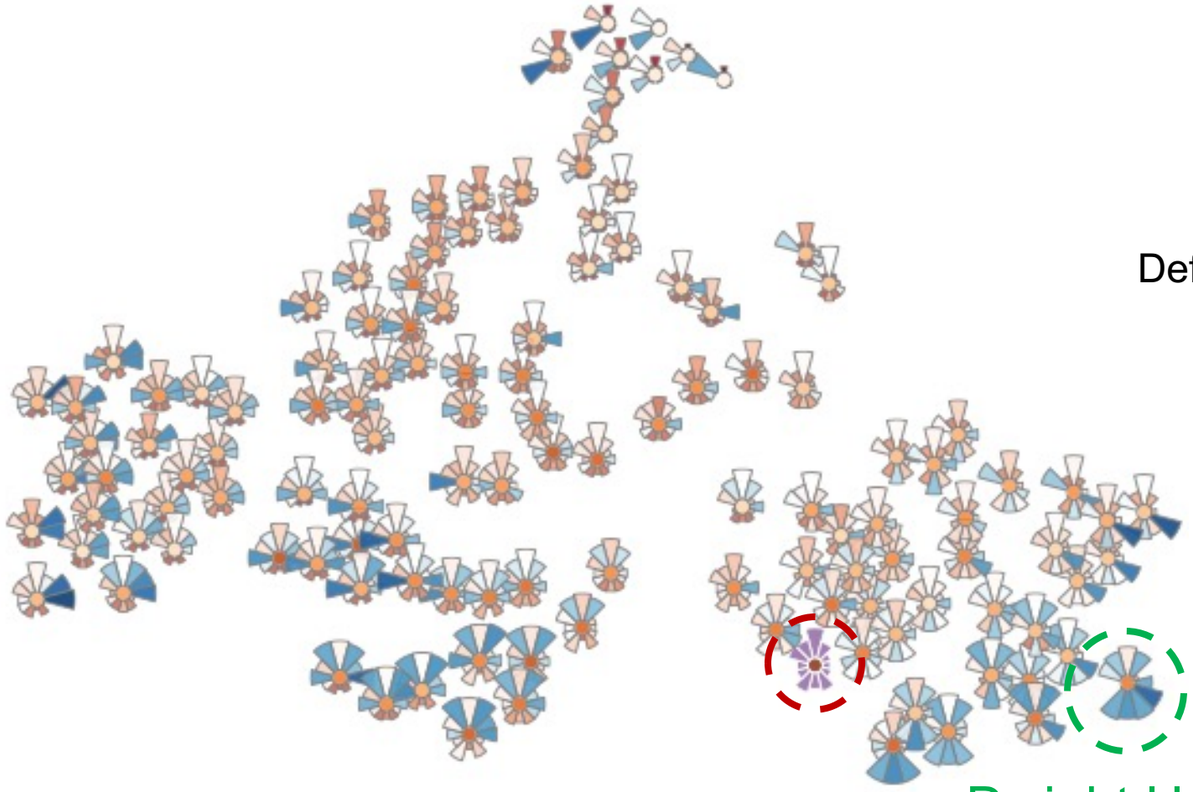
Projection View – Case Studies



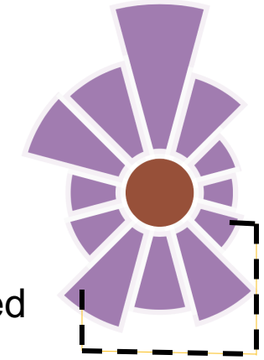


Lamar Odom has the largest dominating score (central circle color)

Projection View – Case Studies

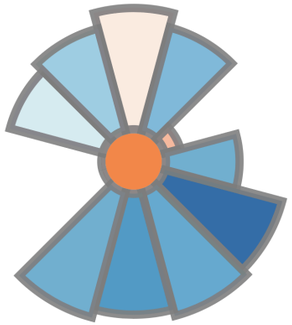


Dwight Howard



Defense-related Attr.

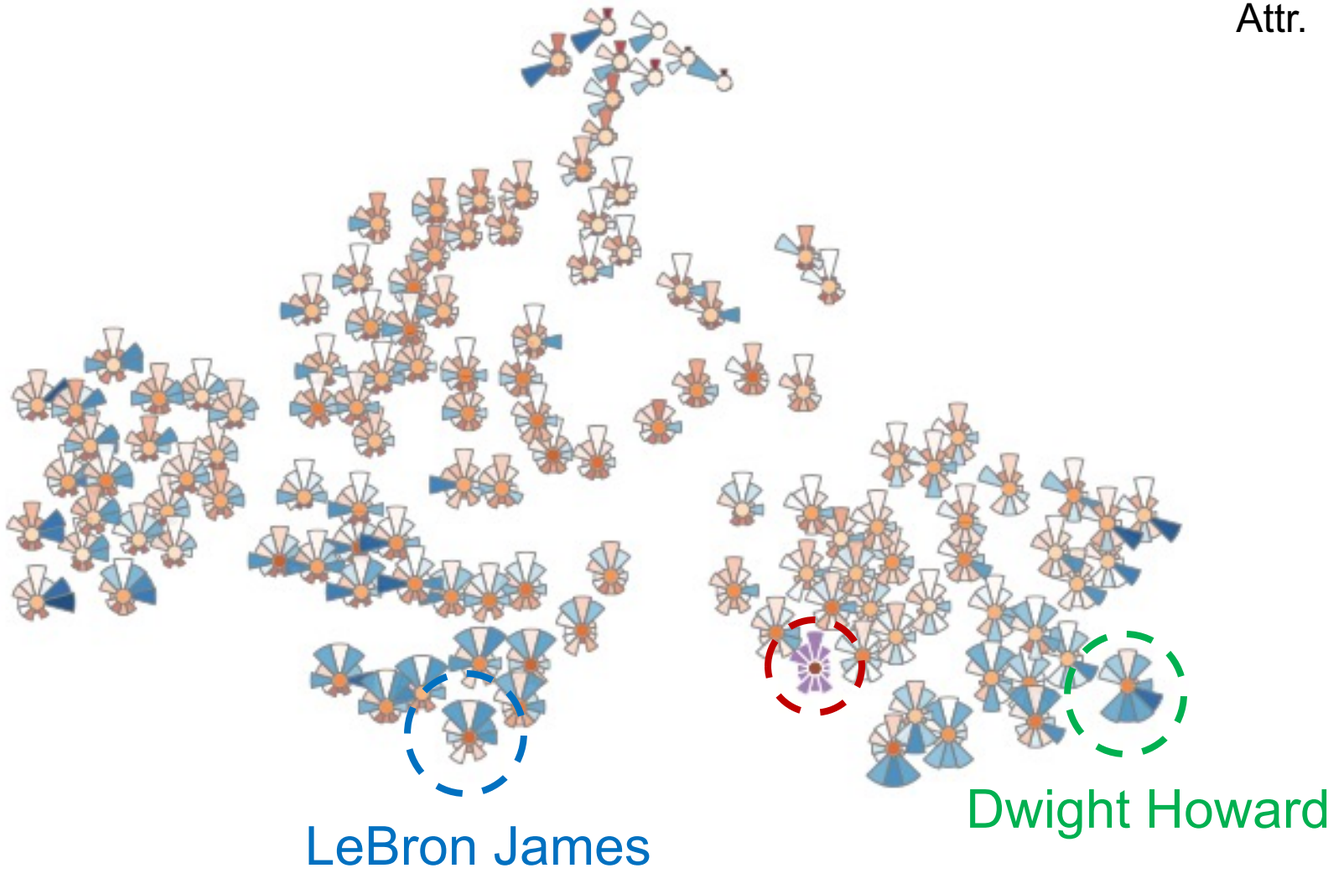
Lamar Odom



Dwight Howard
(defense player)

Switching to *focus mode* : three clusters can be found

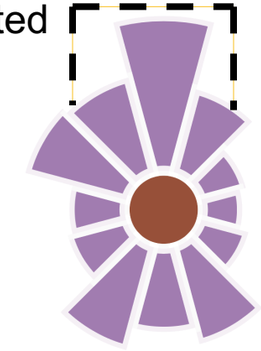
Projection View – Case Studies



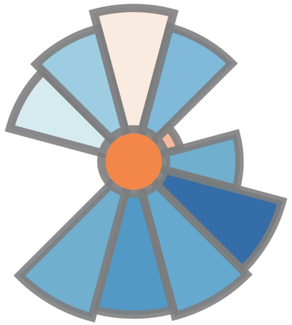
LeBron James

Dwight Howard

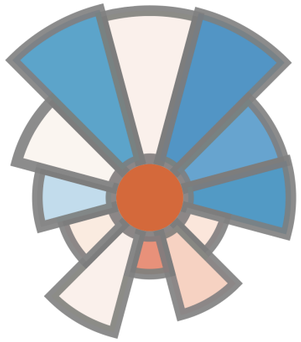
Point made-related Attr.



Lamar Odom



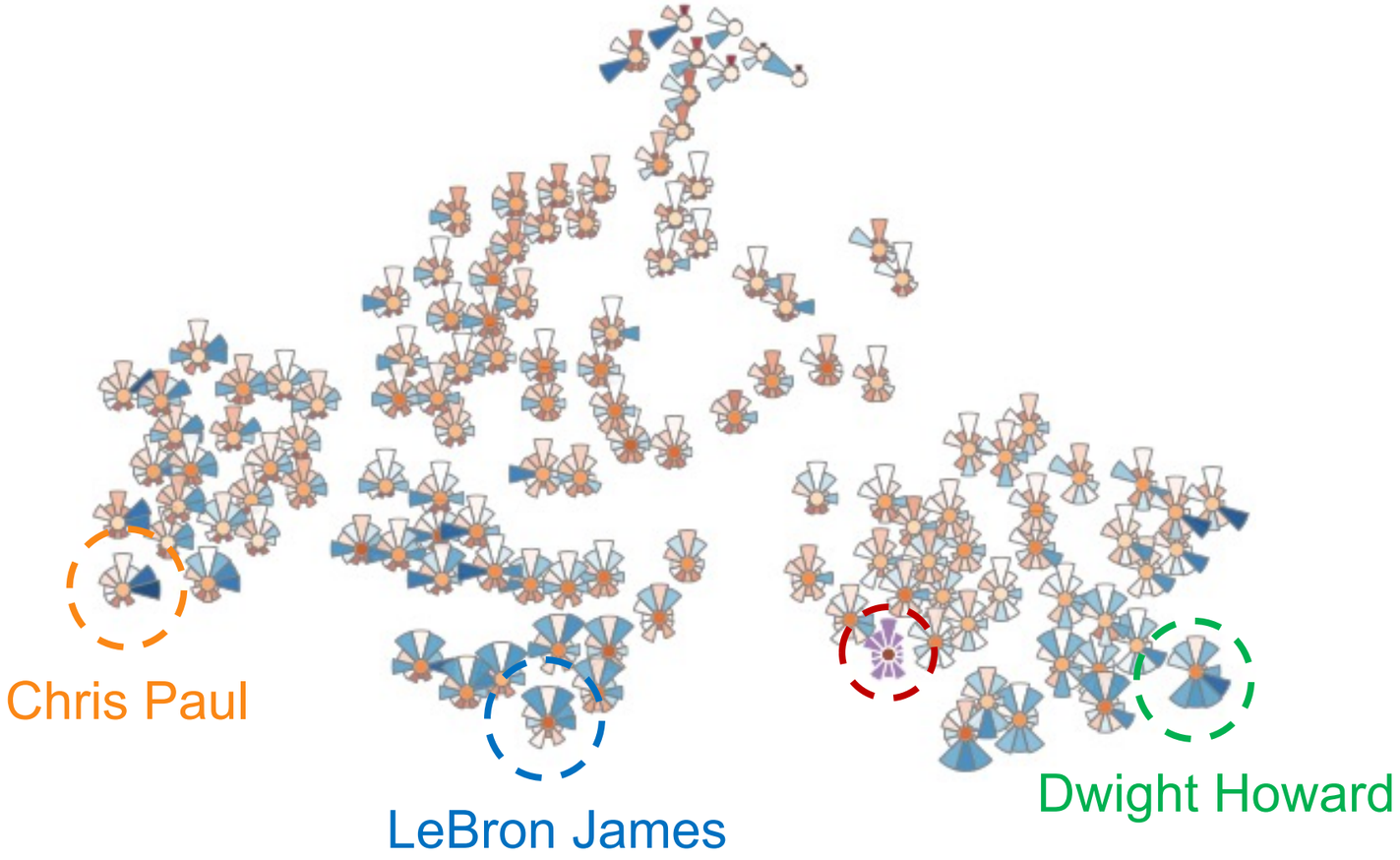
Dwight Howard (defense player)



LeBron James (pointer player)

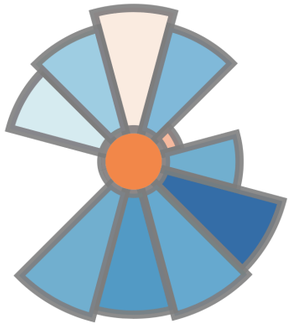
Switching to *focus mode*: three clusters can be found

Projection View – Case Studies

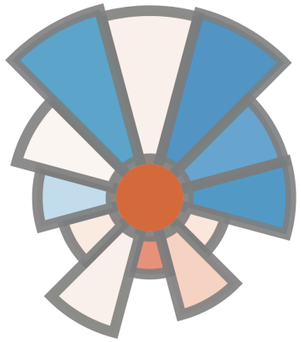


Switching to *focus mode* : three clusters can be found

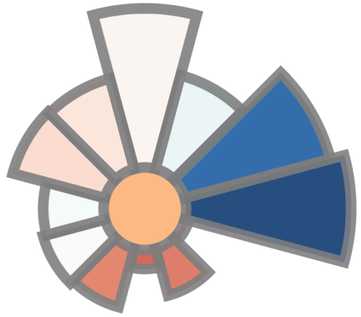
Lamar Odom



Dwight Howard
(defense player)



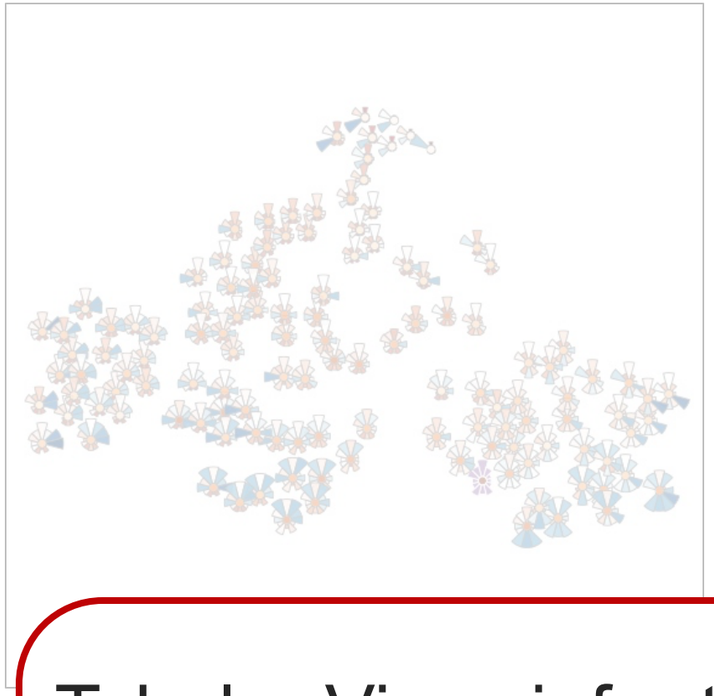
LeBron James
(point player)



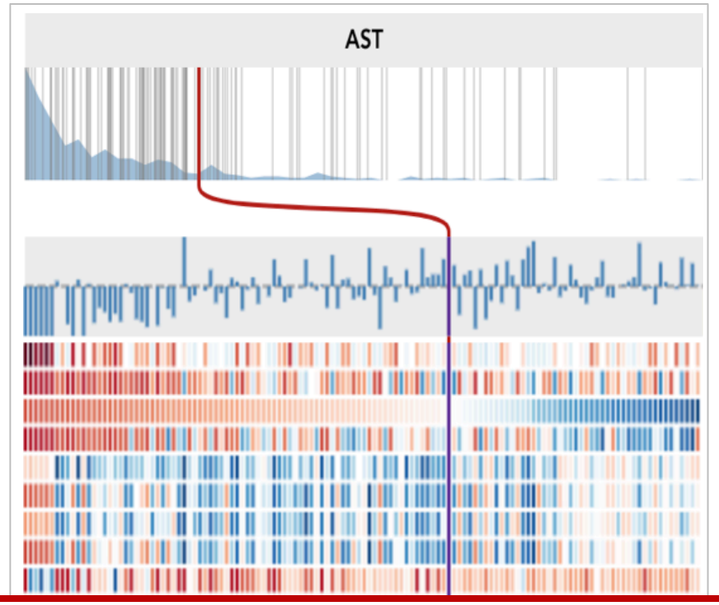
Chris Paul
(assist player)

SkyLens – Tabular View

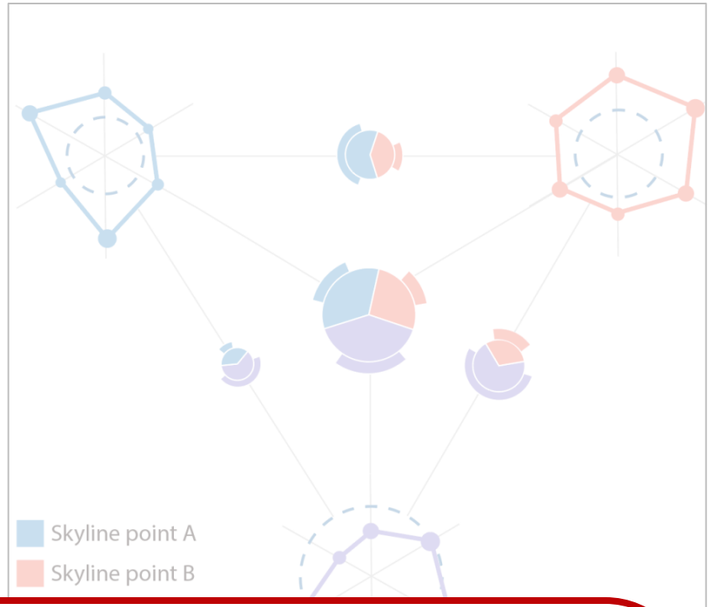
Projection View



Tabular View



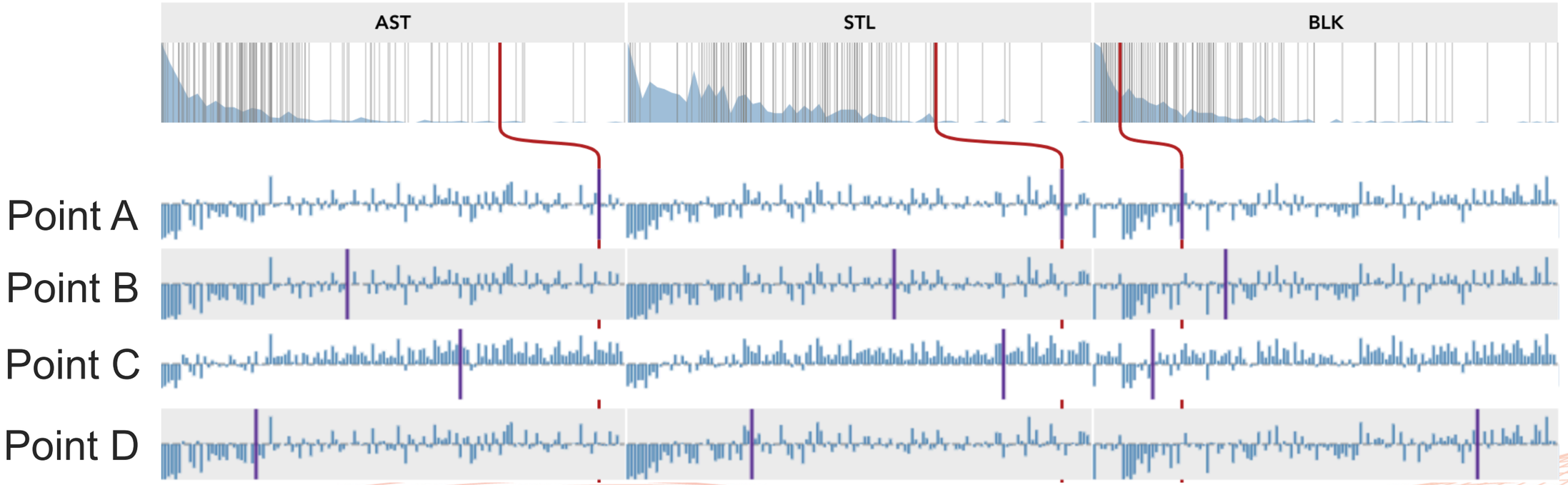
Comparison View



Tabular View: infer the underlying reasons that make a point in skyline

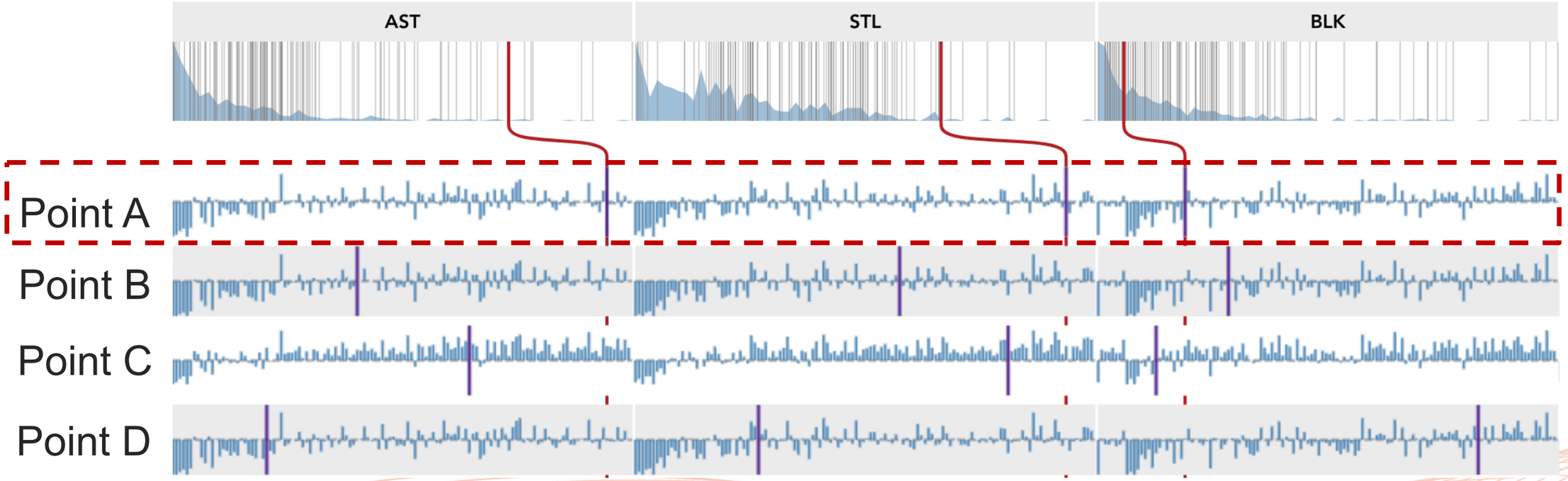
Tabular View

- Methods: matrix representation & in-cell bar chart visualization



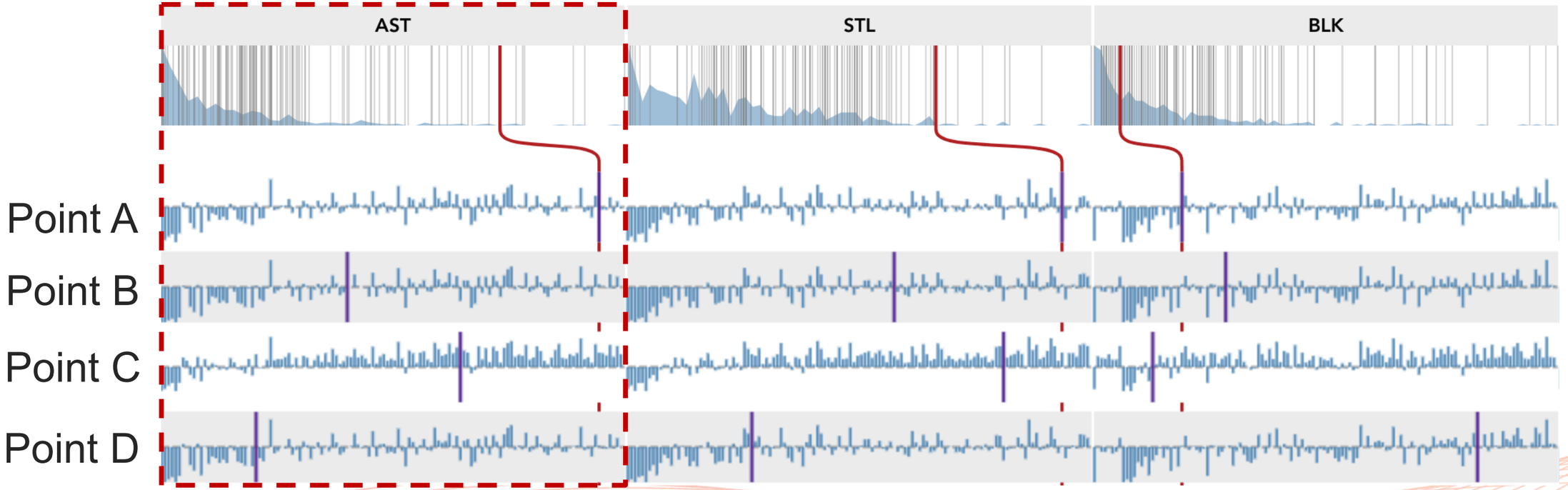
Tabular View

- Methods: matrix representation & in-cell bar chart visualization
  - Each row represents a skyline point



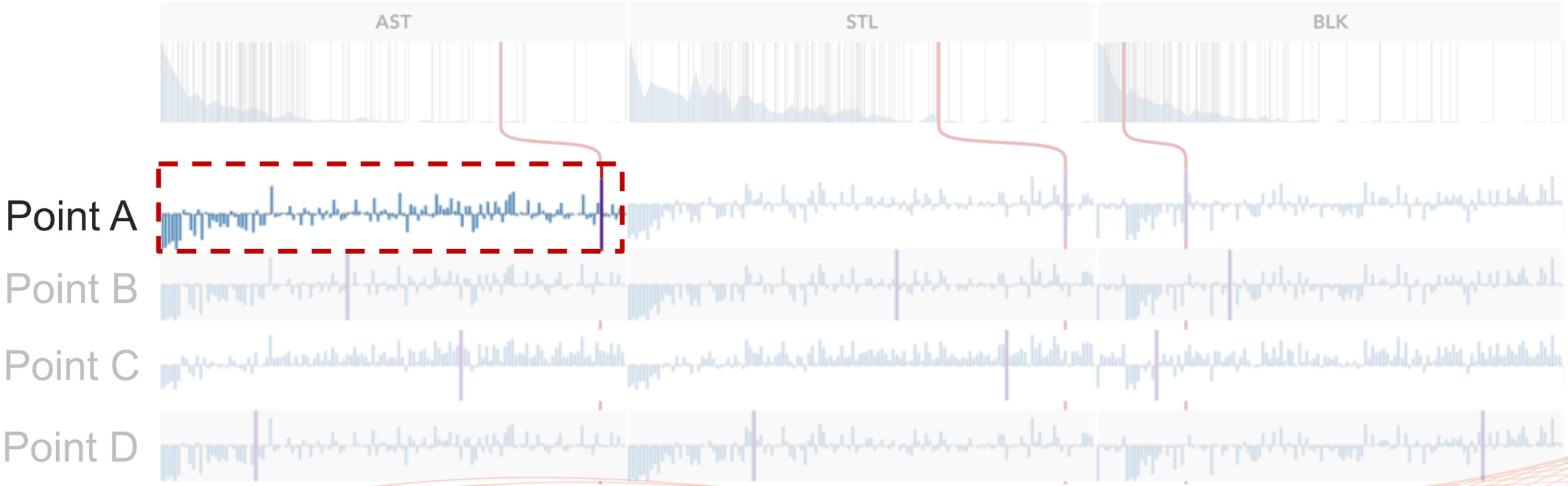
Tabular View

- Methods: matrix representation & in-cell bar chart visualization
  - Each row represents a skyline point
  - Each column represents an attribute



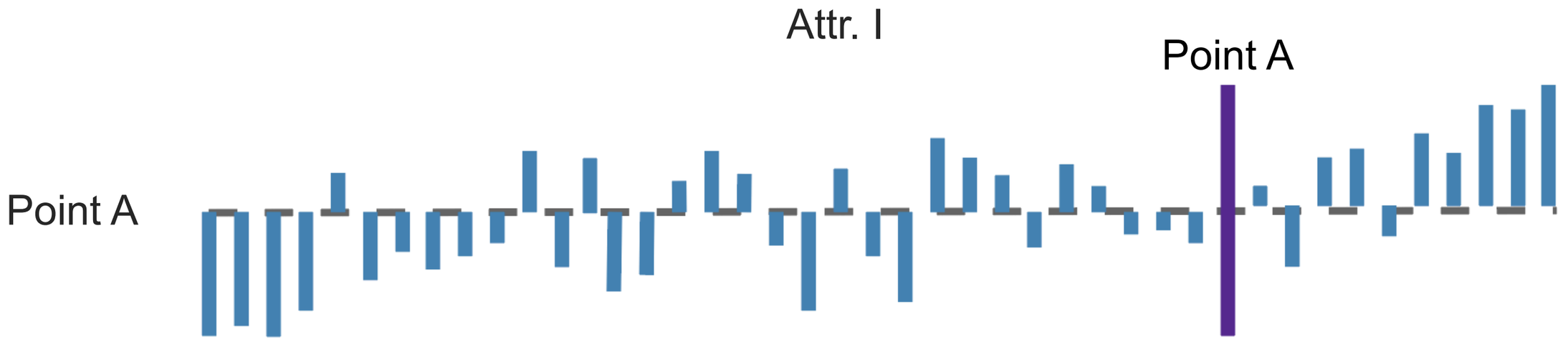
Tabular View

- Table cell – divergent bar chart visualization
  - Goal: summarize the overall differences among skyline points



Tabular View

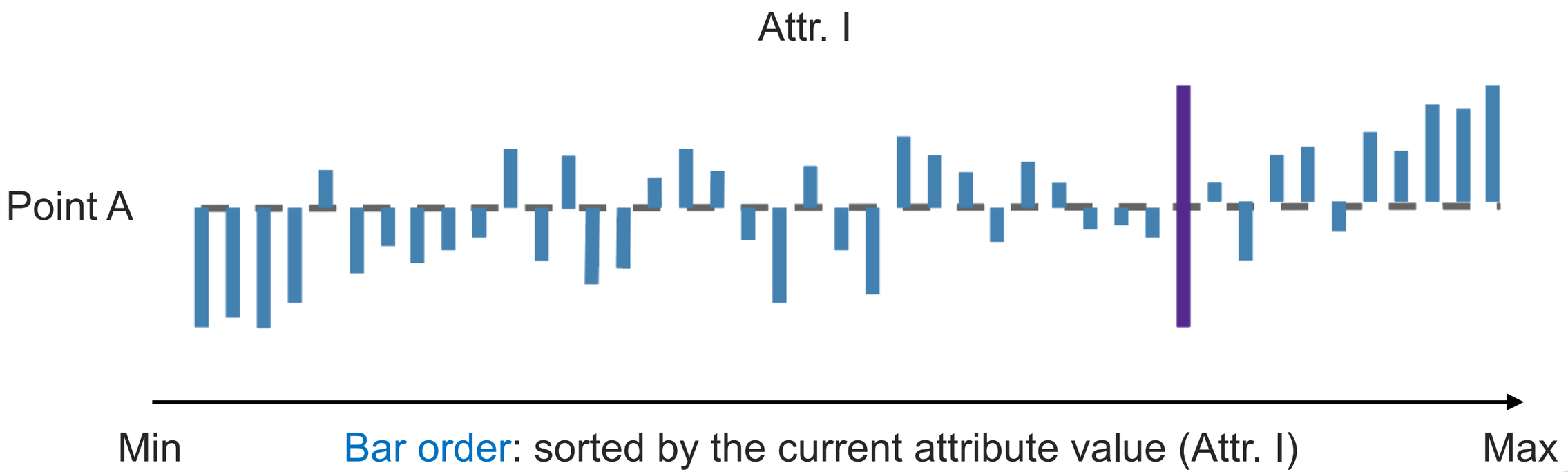
- Table cell – divergent bar chart visualization
  - Goal: summarize the overall differences between skyline points



Each vertical bar represents a skyline point: current point (Point A) other points

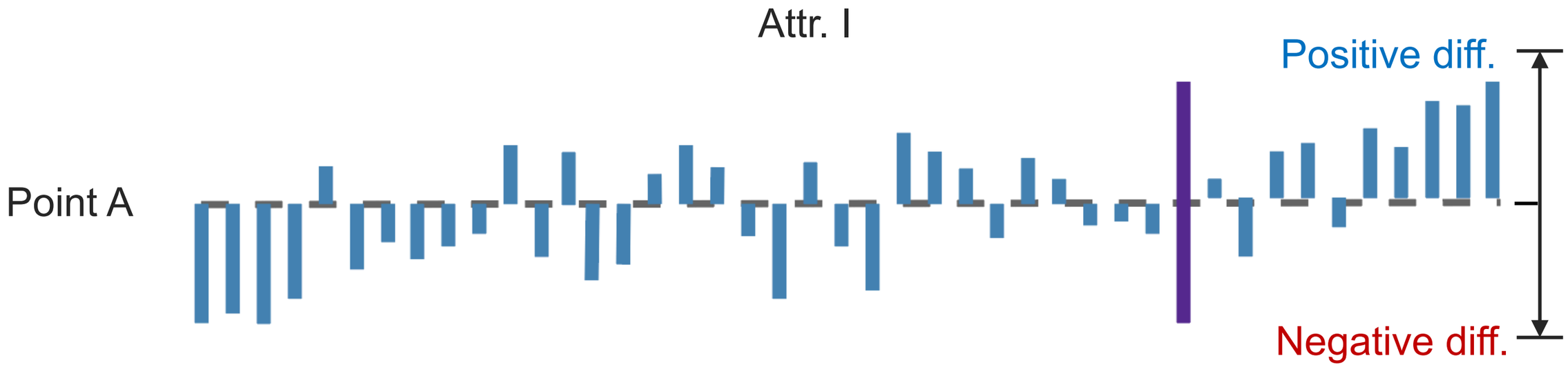
Tabular View

- Table cell – divergent bar chart visualization
  - Goal: summarize the overall differences between skyline points



Tabular View

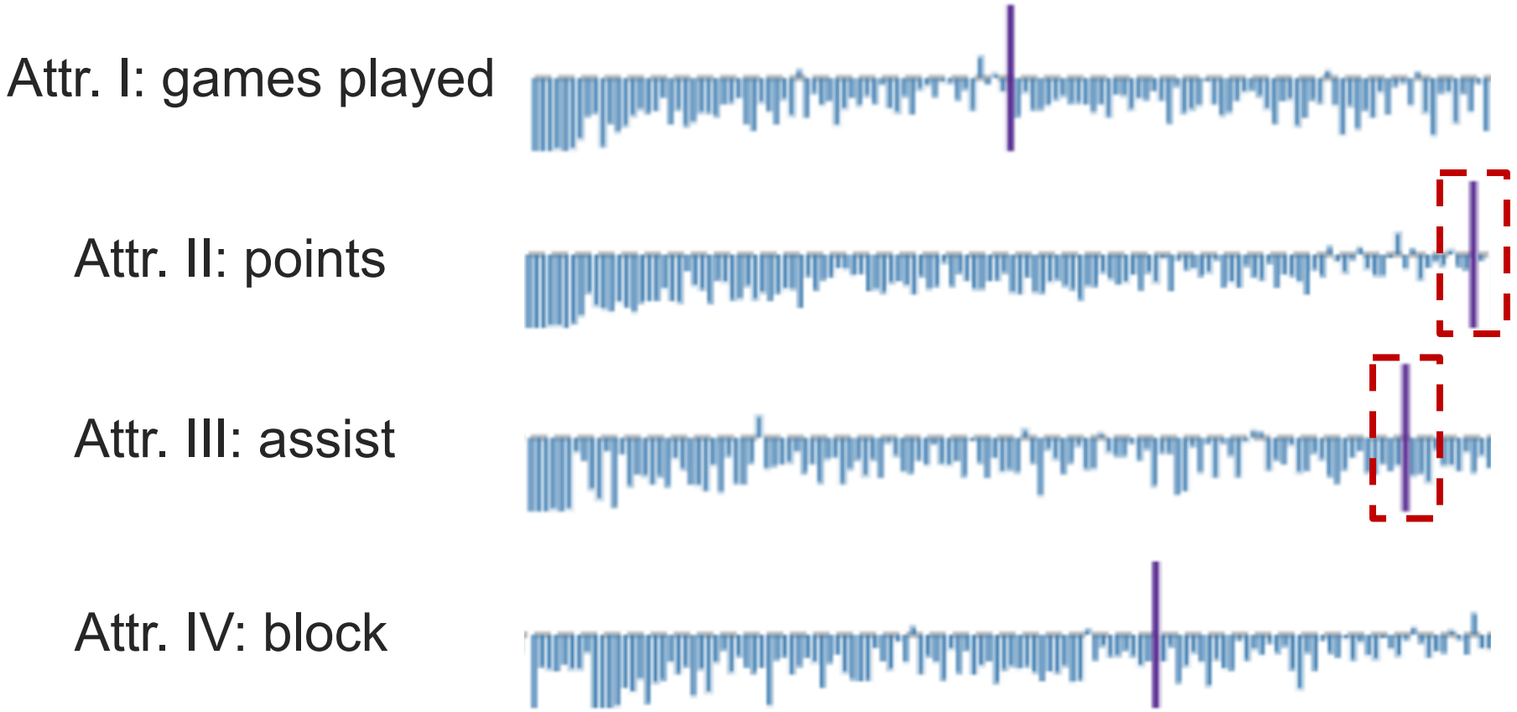
- Table cell – divergent bar chart visualization
  - Goal: summarize the overall differences between skyline points



Bar length: other skyline points' average value differences compared with point A

Tabular View – Case Studies

- Table cell – divergent bar chart visualization
  - Goal: summarize the overall differences between skyline points

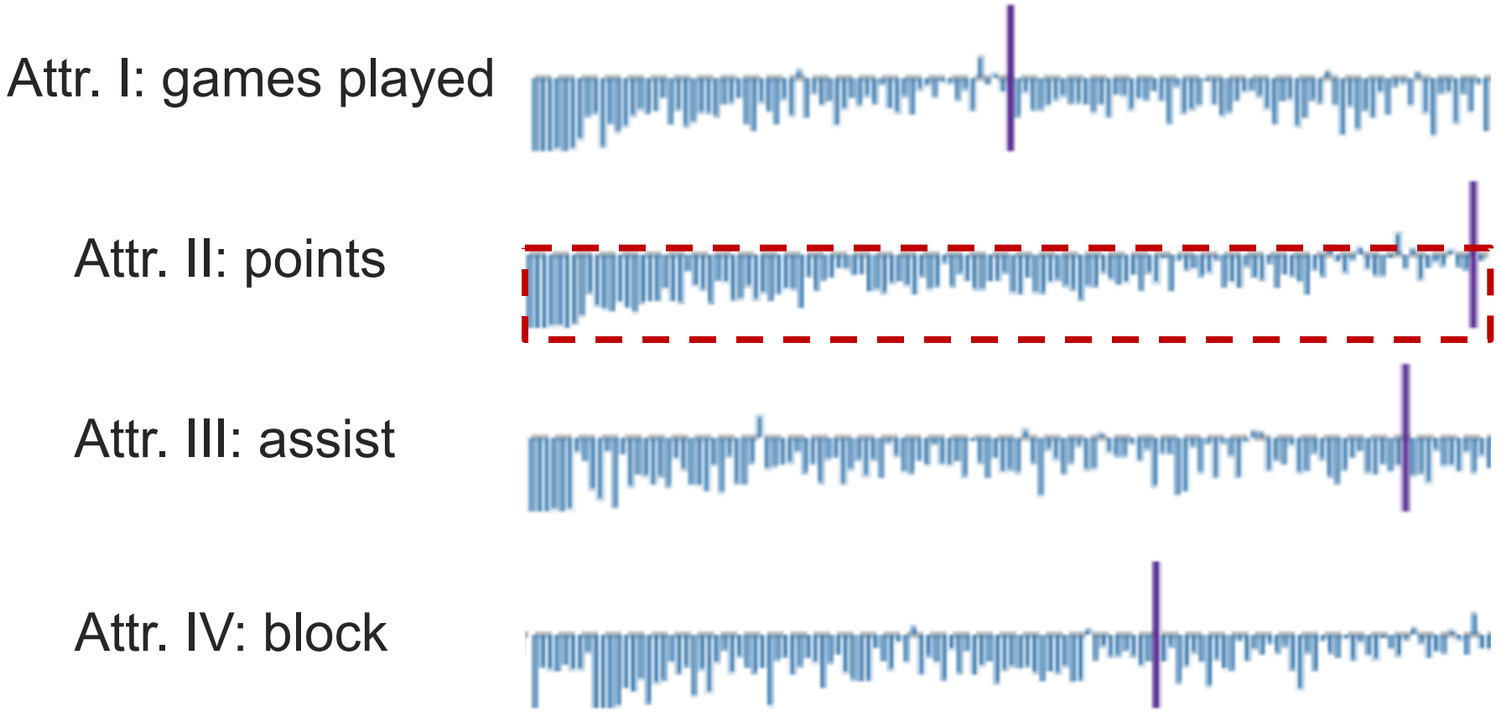


LeBron James:

- High ranking on **points** & **assist**

Tabular View – Case Studies

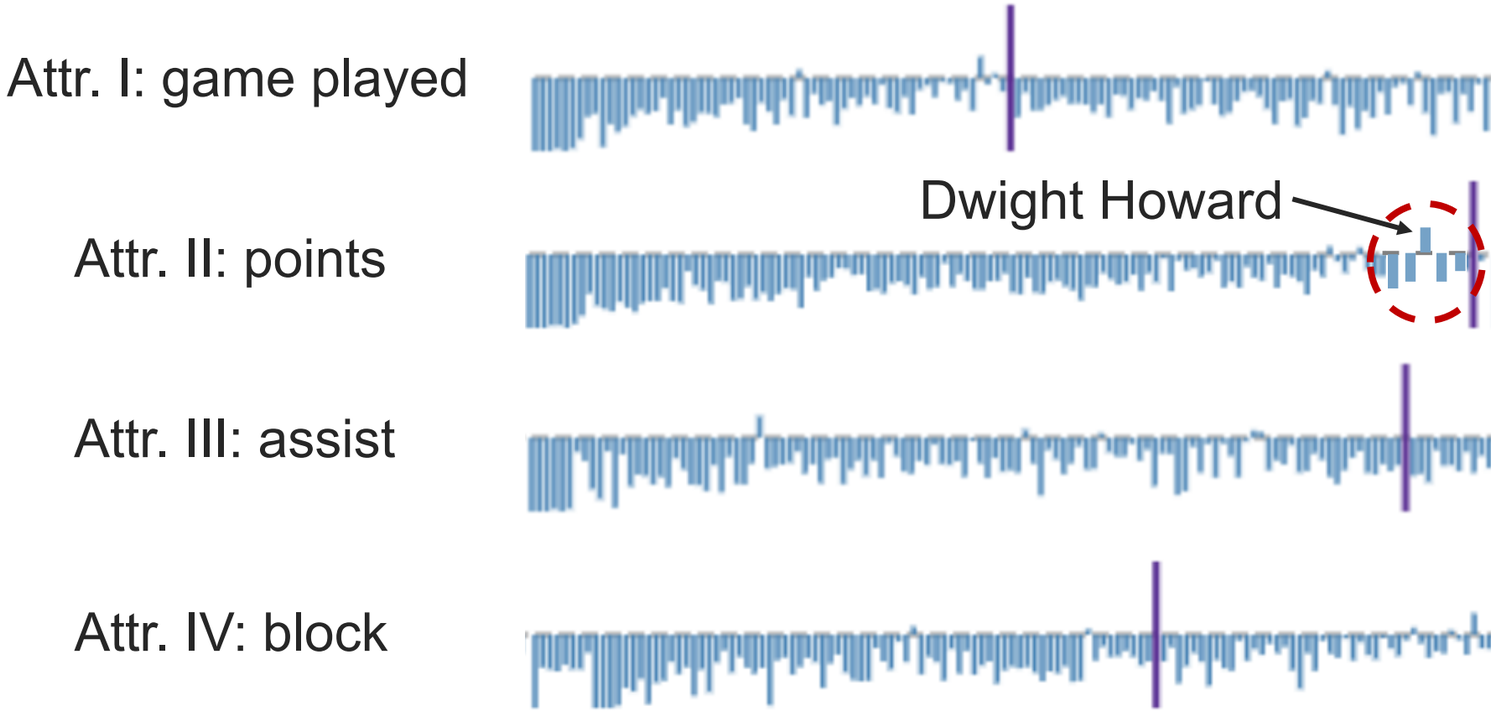
- Table cell – divergent bar chart visualization
  - Goal: summarize the overall differences between skyline points



LeBron James:
- High ranking in points & assist
- **Better** overall performance than most skyline points

Tabular View – Case Studies

- Table cell – divergent bar chart visualization
  - Goal: summarize the overall differences between skyline points



LeBron James:

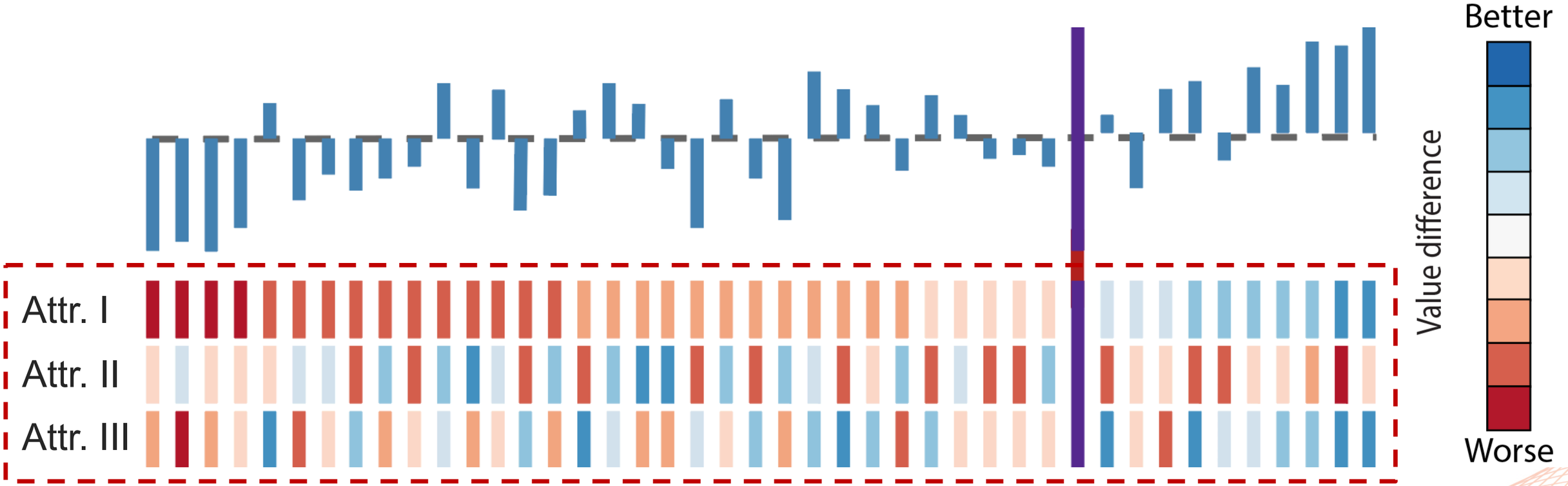
- High ranking in points & assist
- Better overall performance than most skyline points
- Dwight has an overall **comparable performance** with LeBron

Tabular View

- Table cell interaction: expanding a row for detailed information

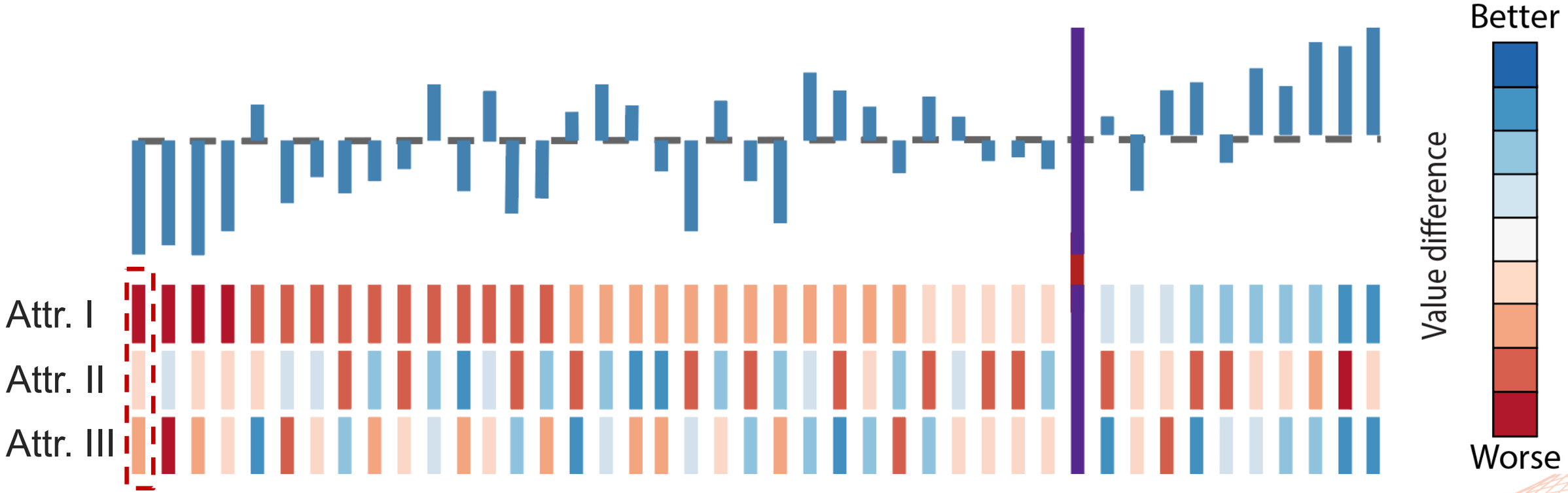
Tabular View

- Table cell interaction: expanding a row for detailed information



Tabular View

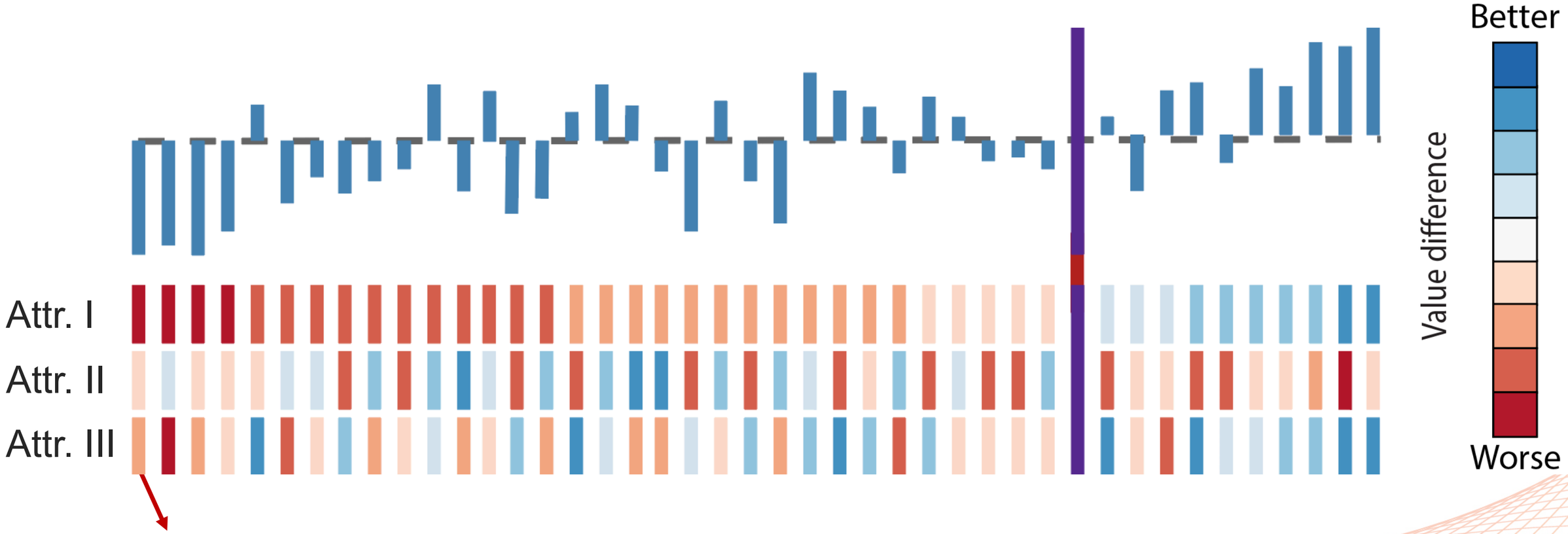
- Table cell interaction: expanding a row for detailed information



Each column is an extension of the corresponding vertical blue bar and represents the same skyline point

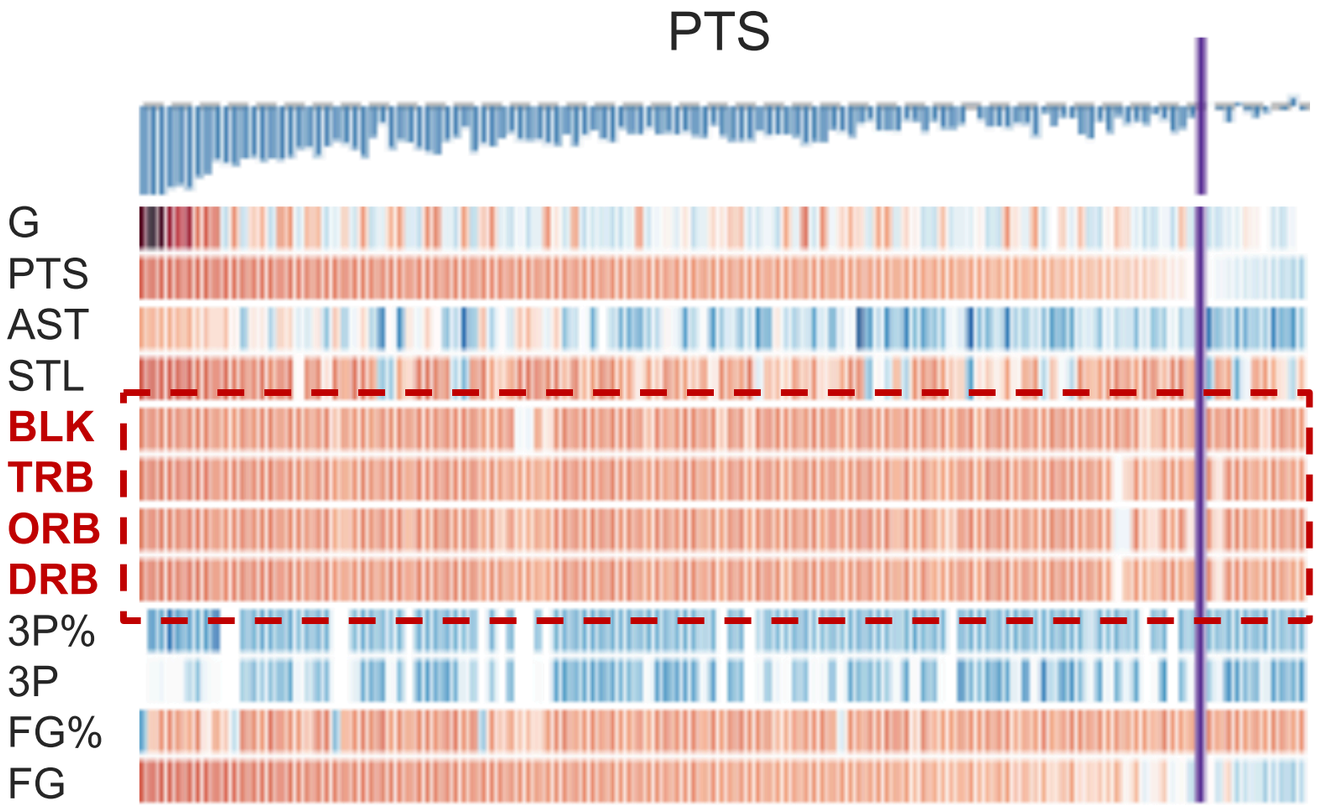
Tabular View

- Table cell interaction: expanding a row for detailed information



Matrix cell color: the value difference of the corresponding attribute (Attr. III)

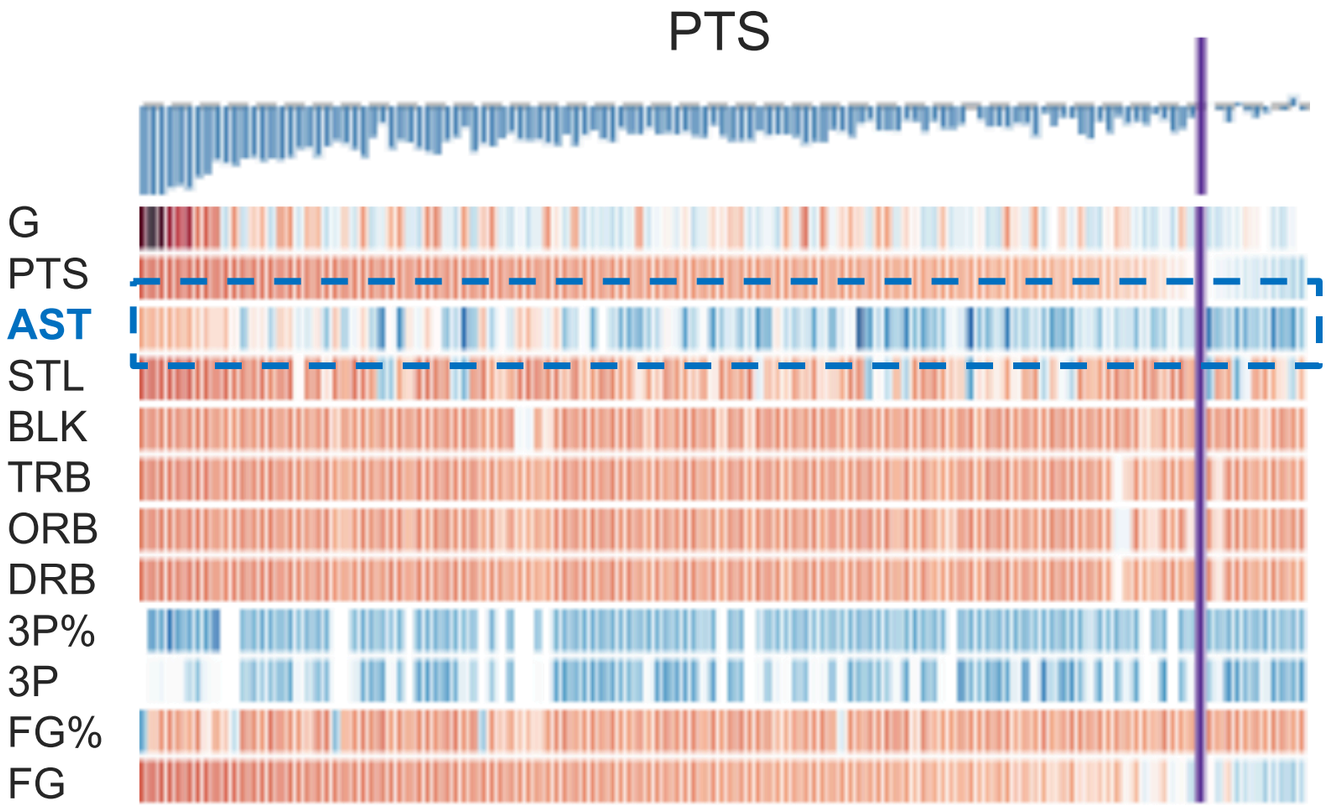
Tabular View – Case Studies



Dwight Howard:

- No players has better performance than him in **defense-related** attributes

Tabular View – Case Studies

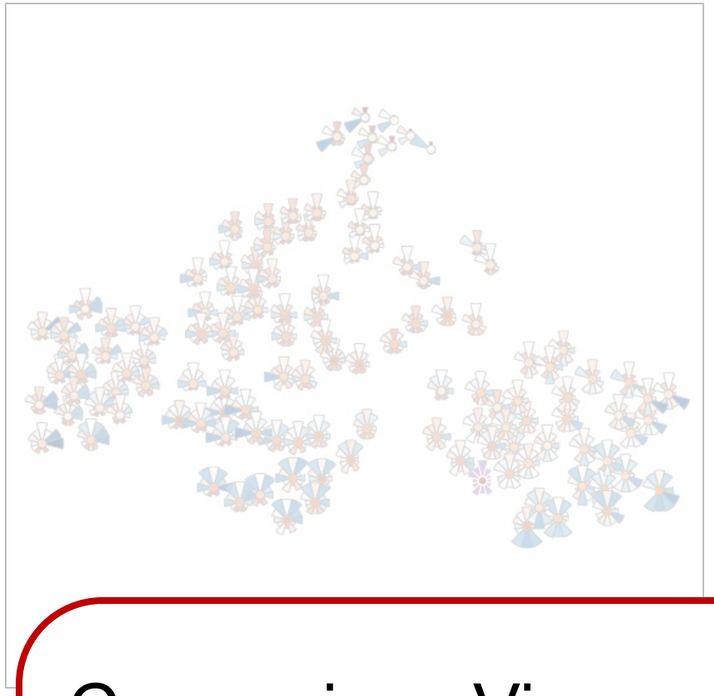


Dwight Howard:

- No players has better performance than him in defense-related attributes
- Many players outperform him in **AST**

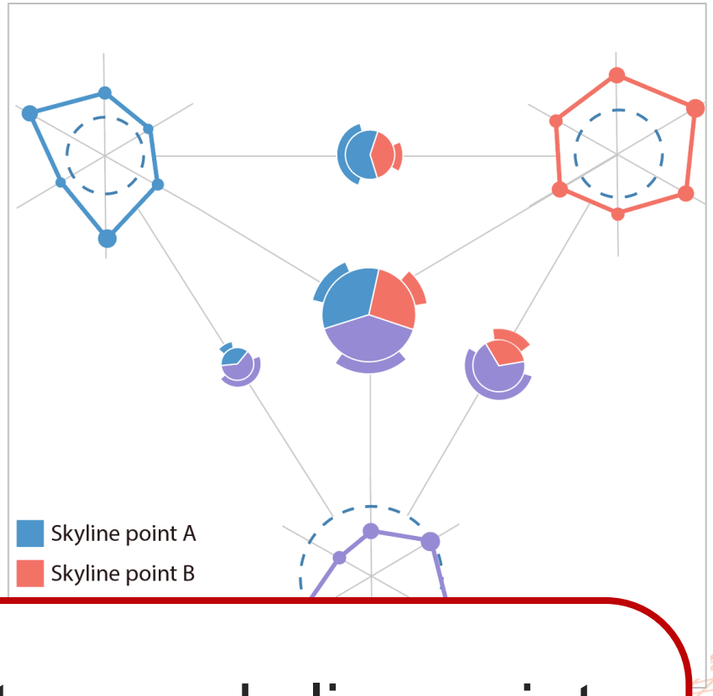
SkyLens – Comparison View

Projection View



Tabular View

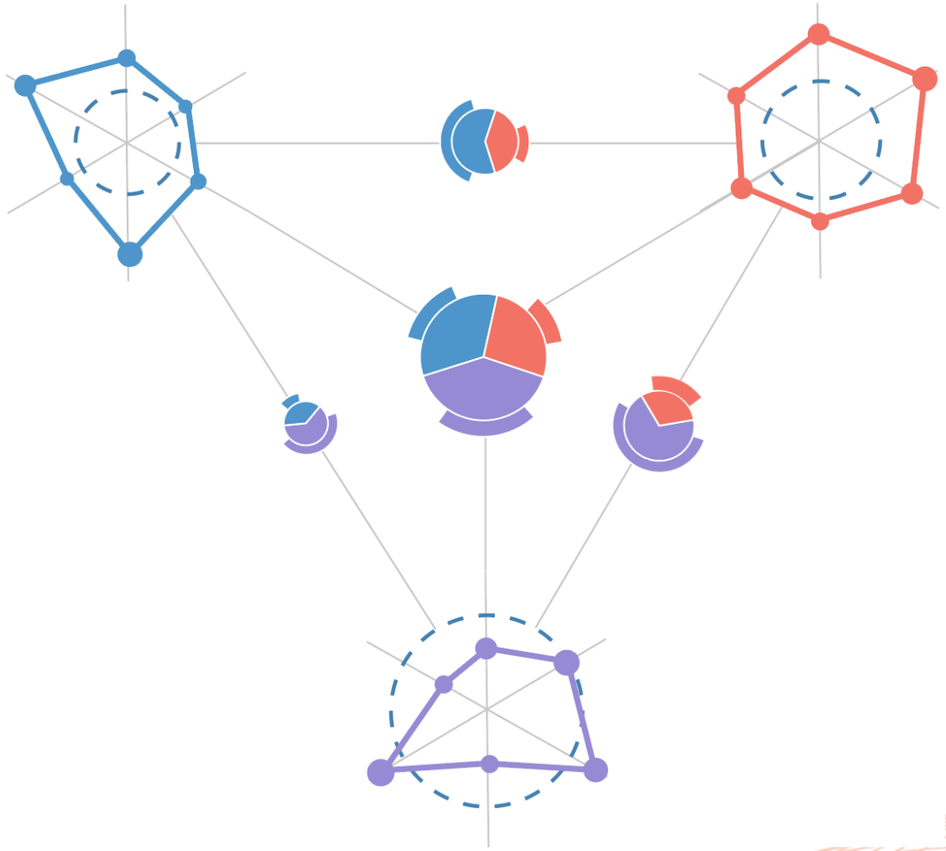
Comparison View



Comparison View: support a thorough comparison between skyline points

Comparison View

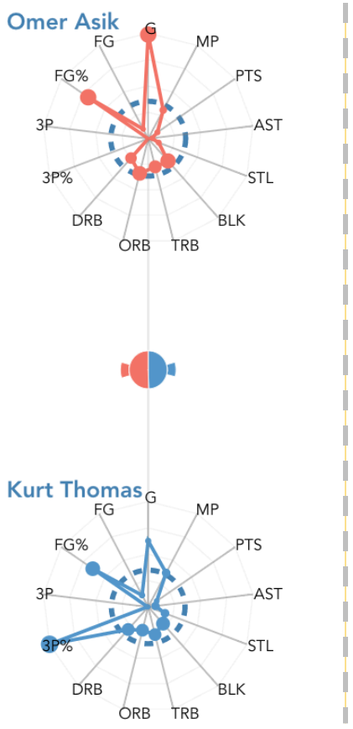
- Methods: radar charts & domination glyphs
  - Comparing attribute values
  - Examining dominating scores
  - Investigating dominated points



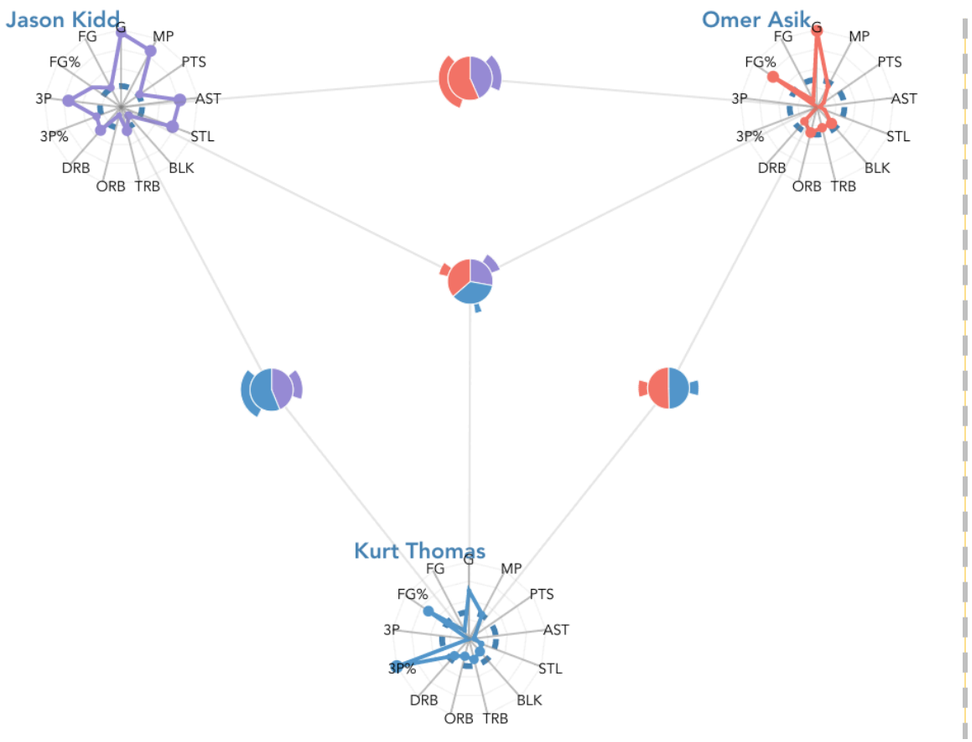
Goal: a thorough comparison
on 2 ~ 5 skyline points

Comparison View

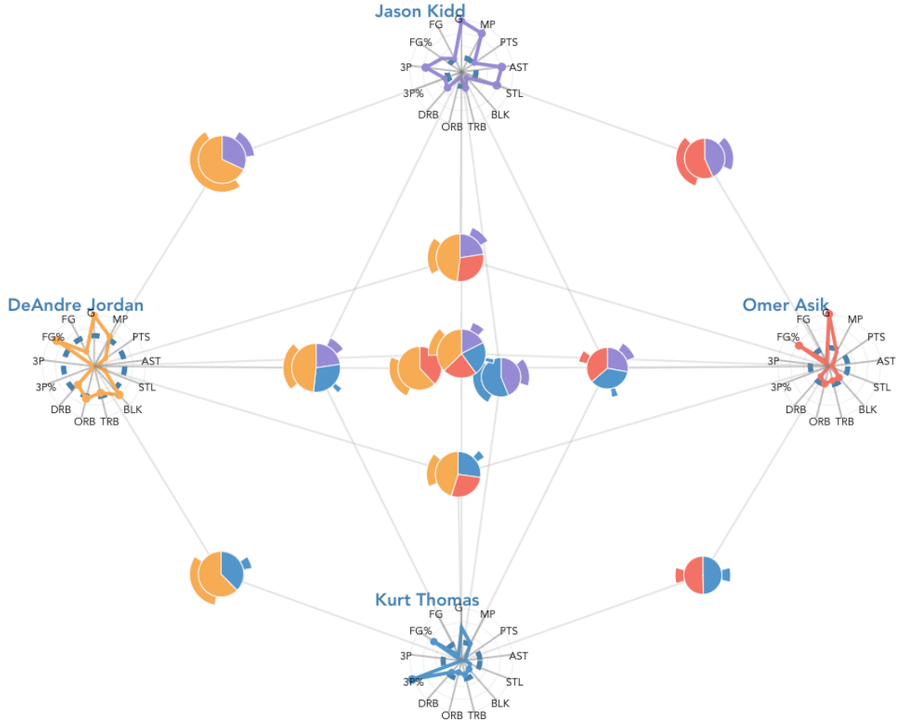
- Radial layout for the radar charts & domination glyphs



2-point comparison

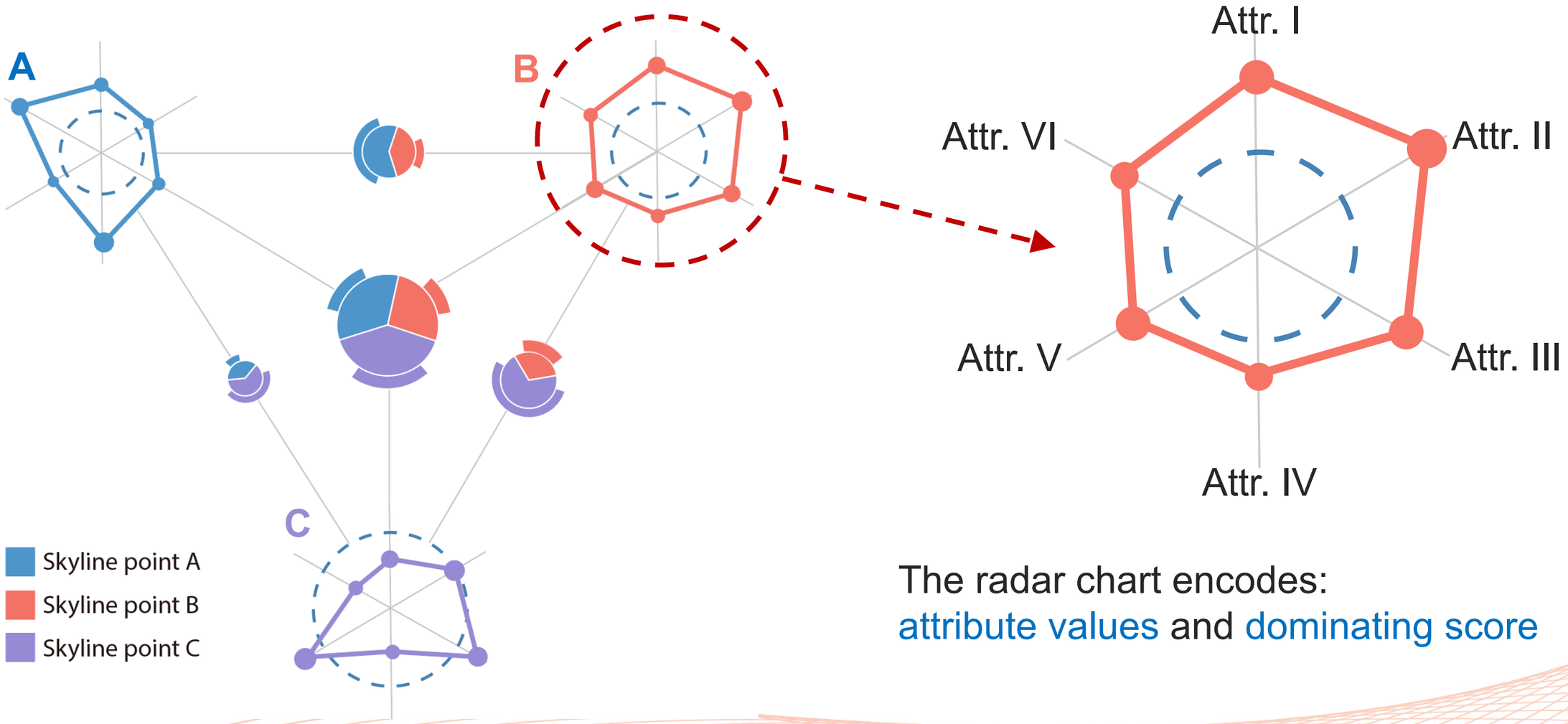


3-point comparison



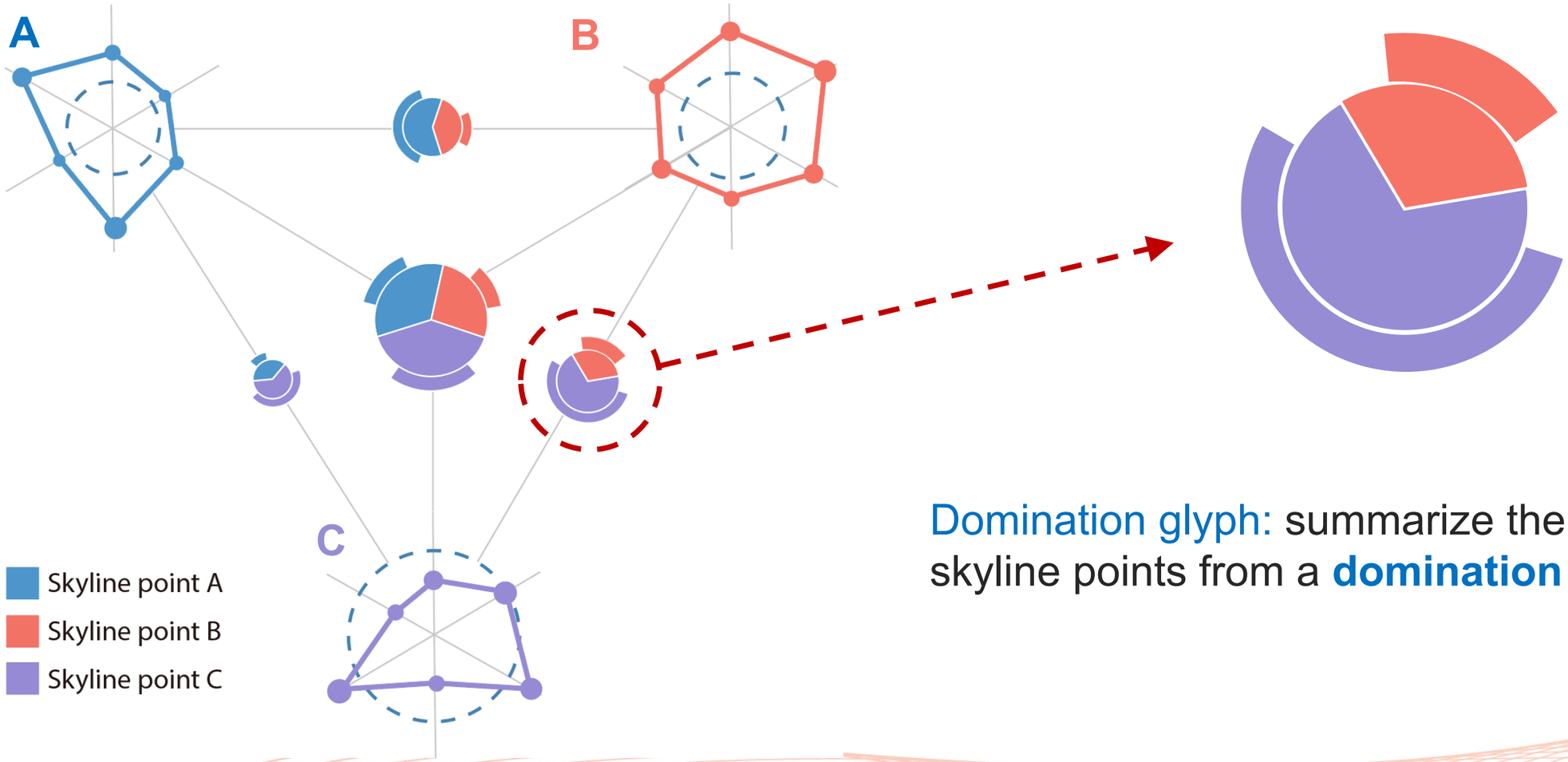
4-point comparison

Comparison View – Radar Chart



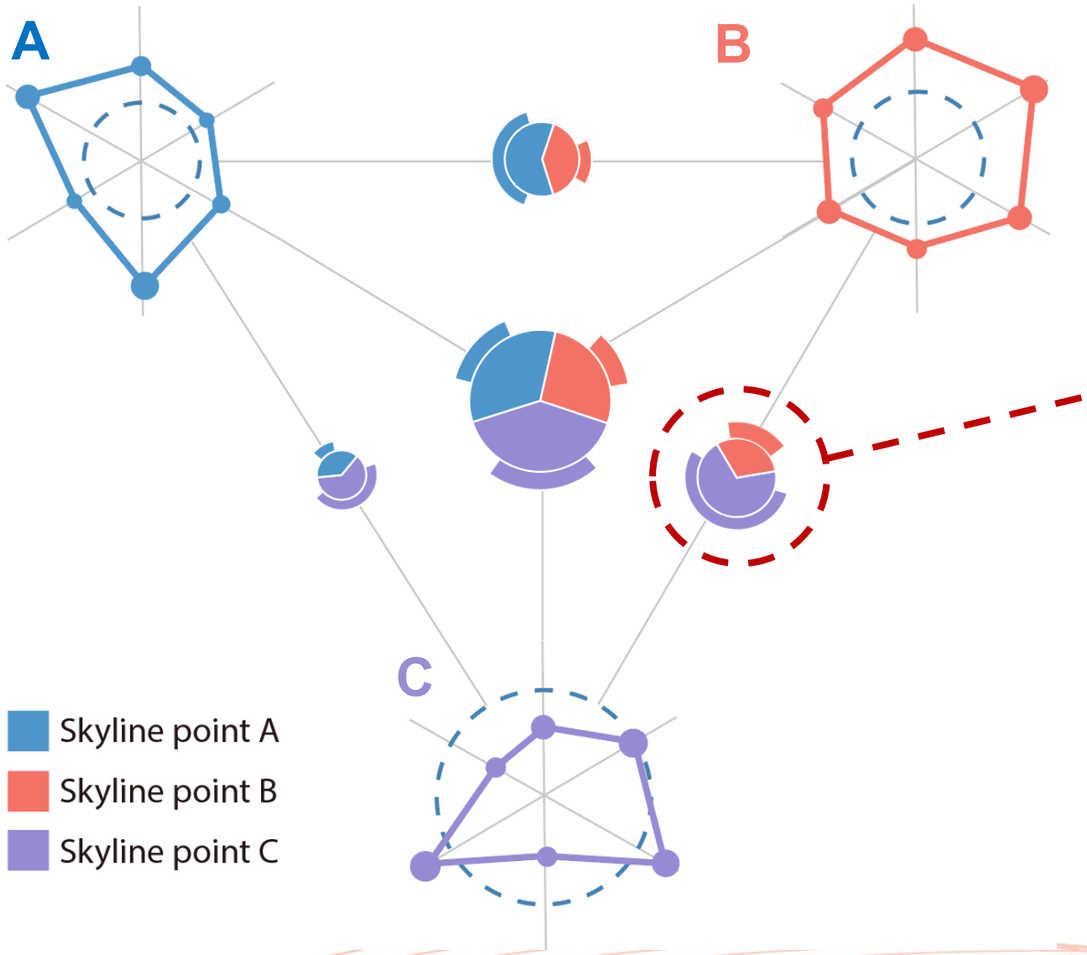
The radar chart encodes:
attribute values and dominating score

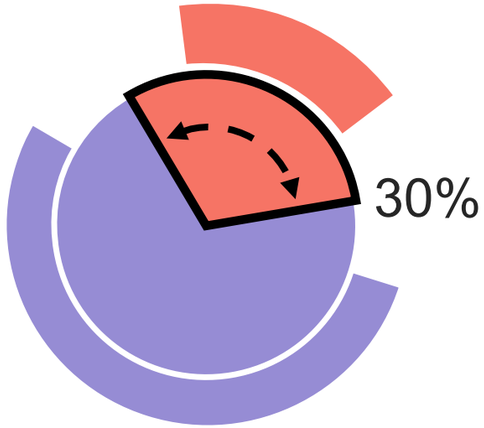
Comparison View – Domination Glyph



Domination glyph: summarize the differences among skyline points from a **domination perspective**.

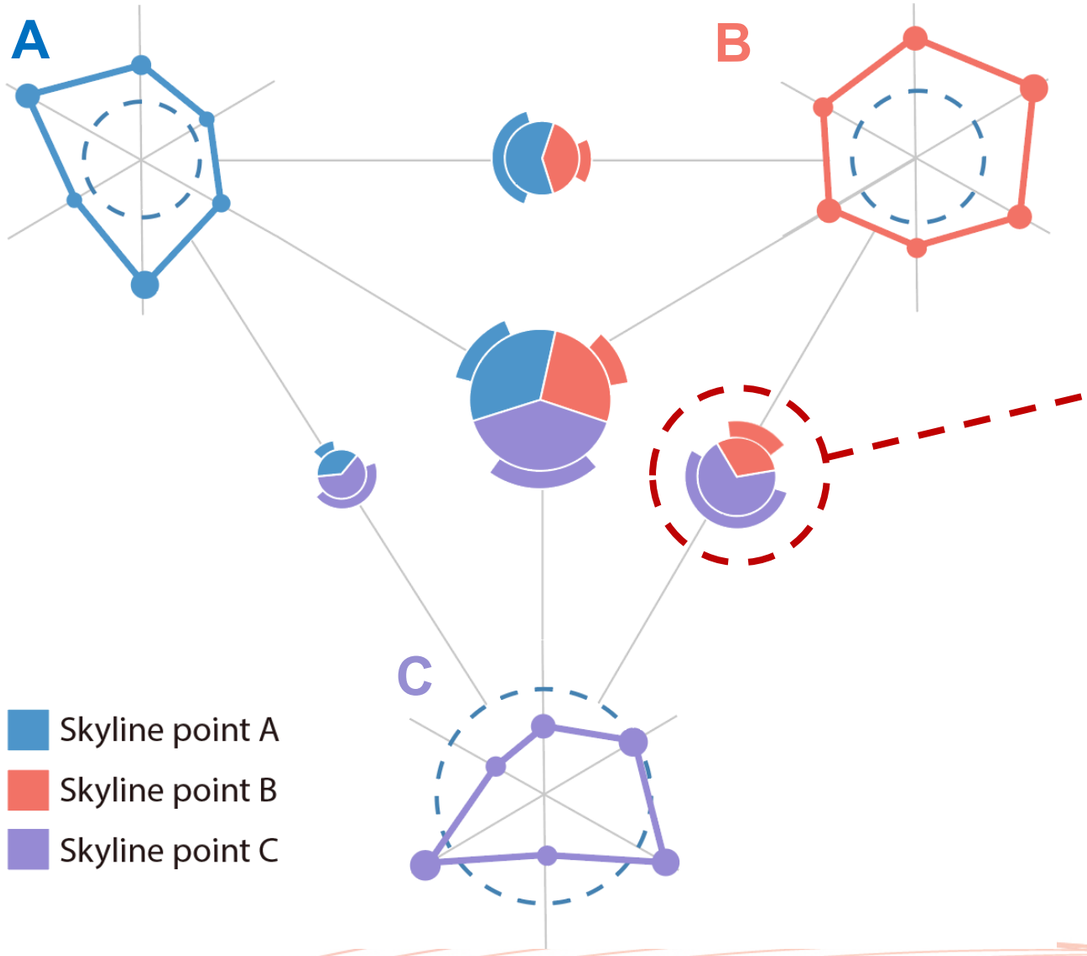
Comparison View – Domination Glyph

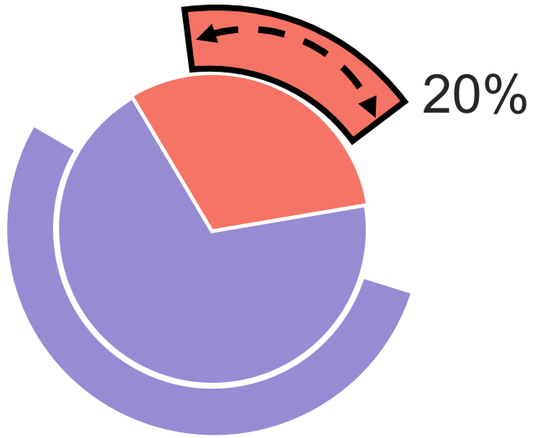




Inner sector angle: the ratio of points that are dominated by **skyline point B**

Comparison View – Domination Glyph

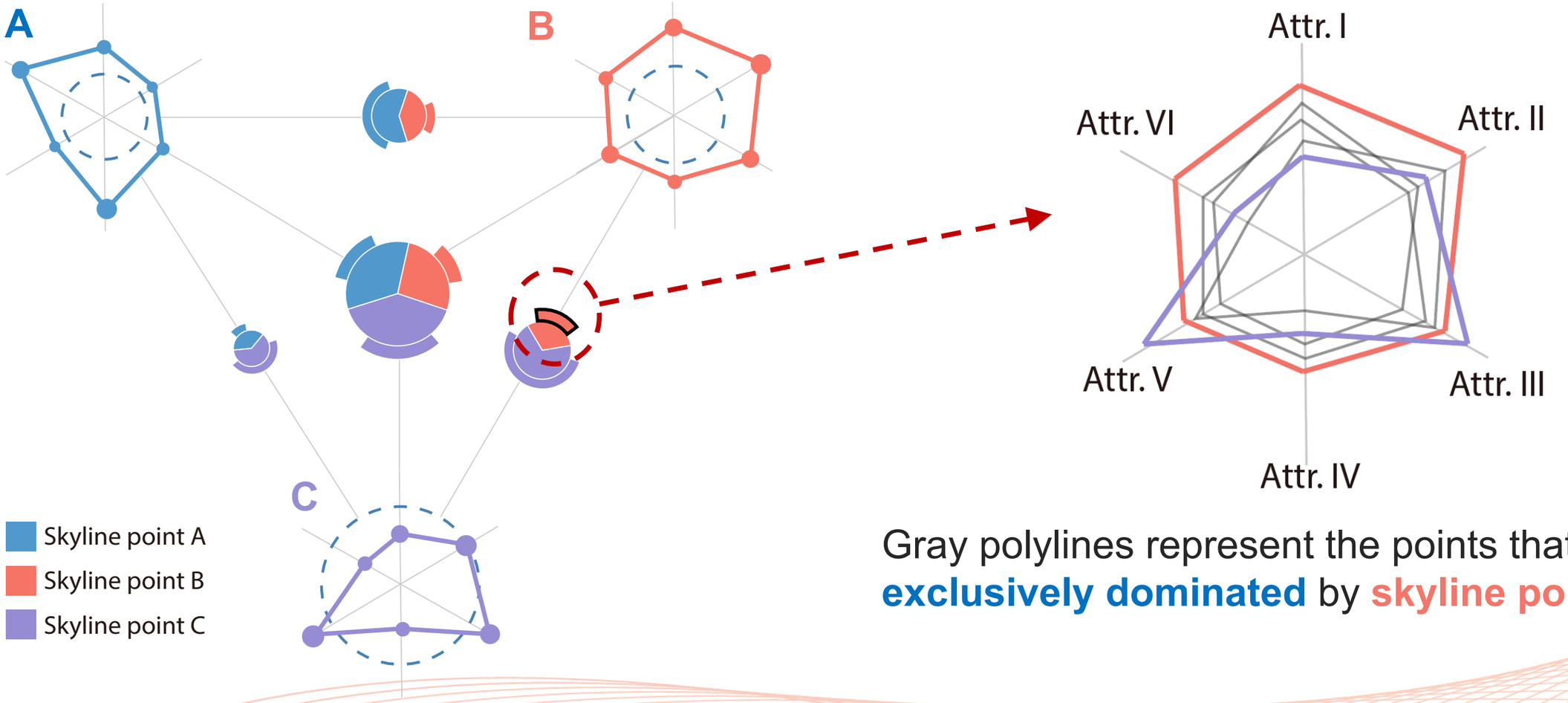




Outer sector angle: the ratio of points that are **exclusively dominated** by **skyline point B**

Comparison View – Domination Glyph Interaction

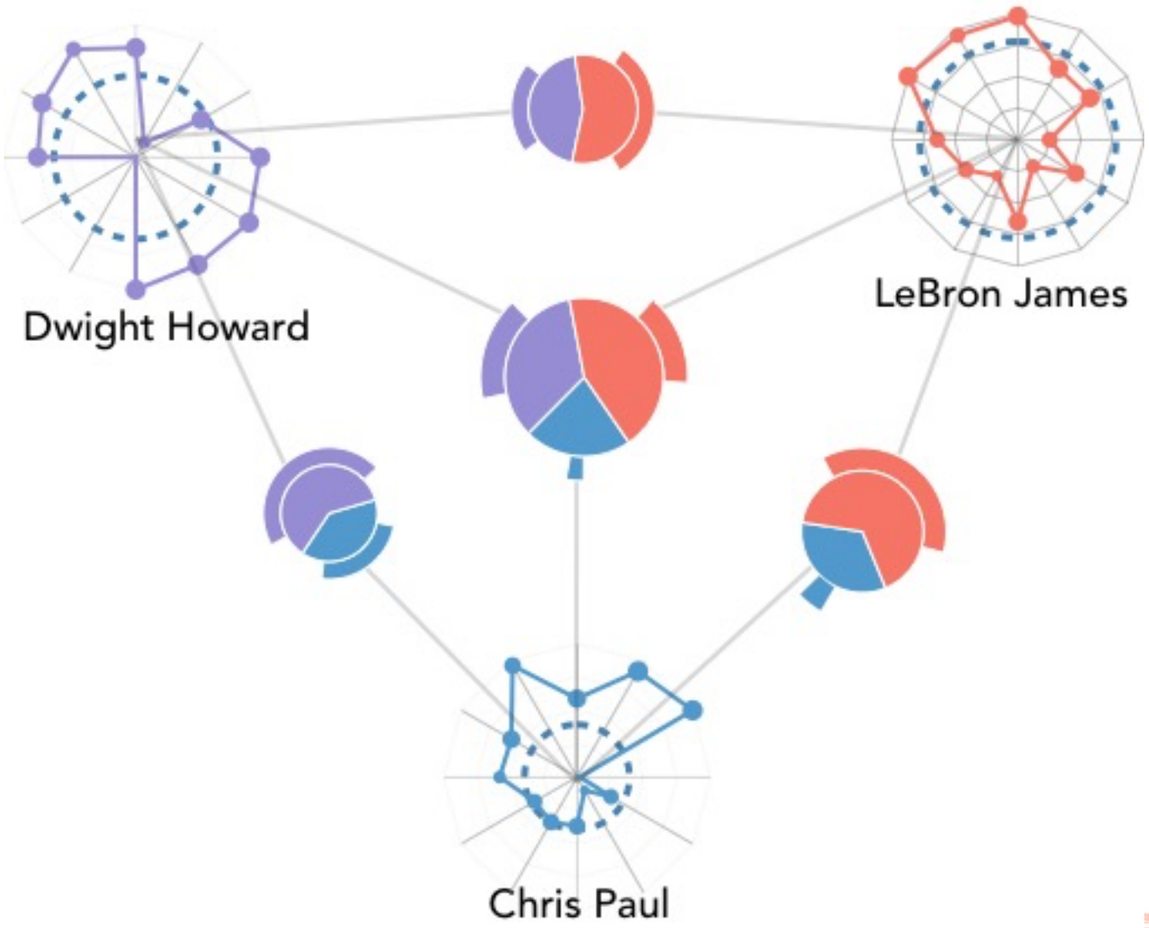
Hovering interaction: pop-up window showing the overlaid radar chart



Gray polylines represent the points that are **exclusively dominated** by **skyline point B**

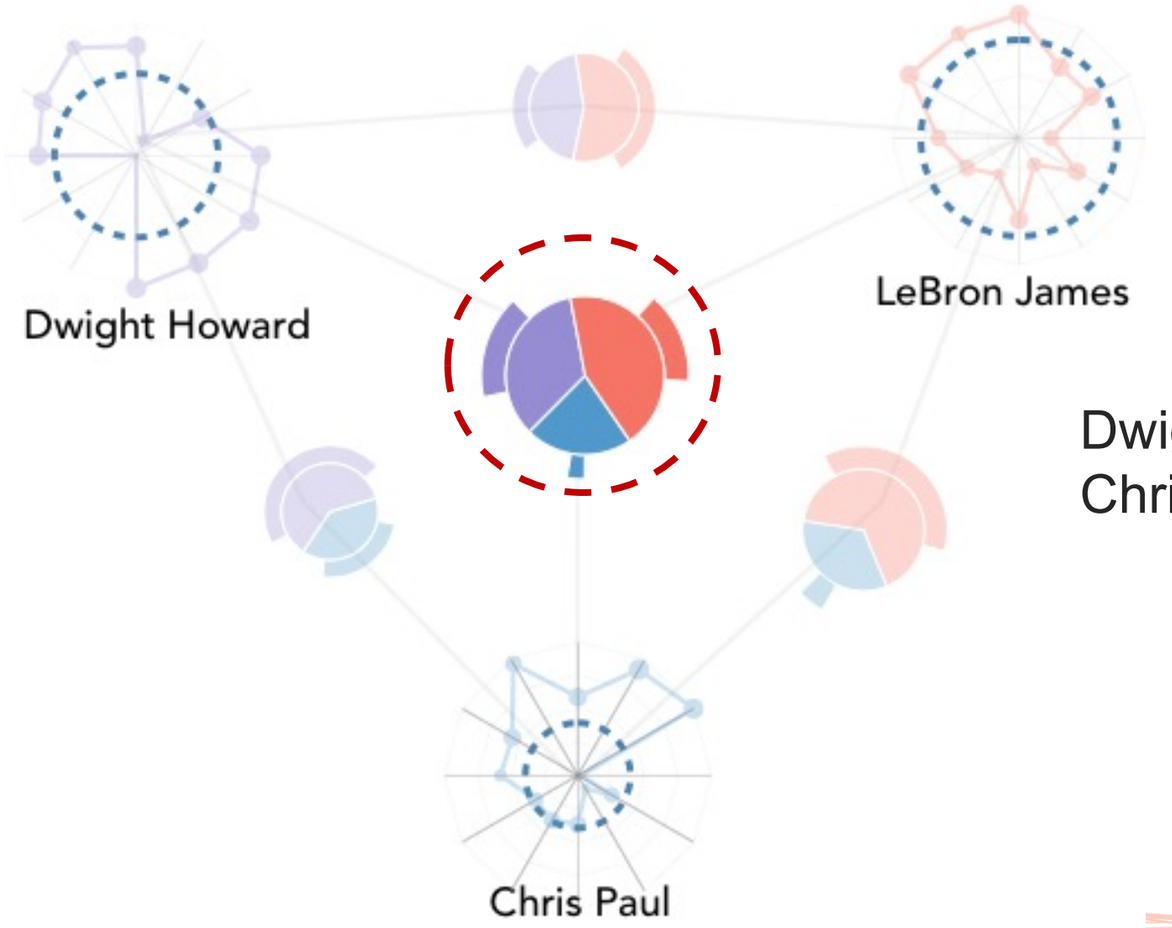
Comparison View – Case Studies

Comparing Dwight, LeBron, and Chris in the perspective of domination relation



Comparison View – Case Studies

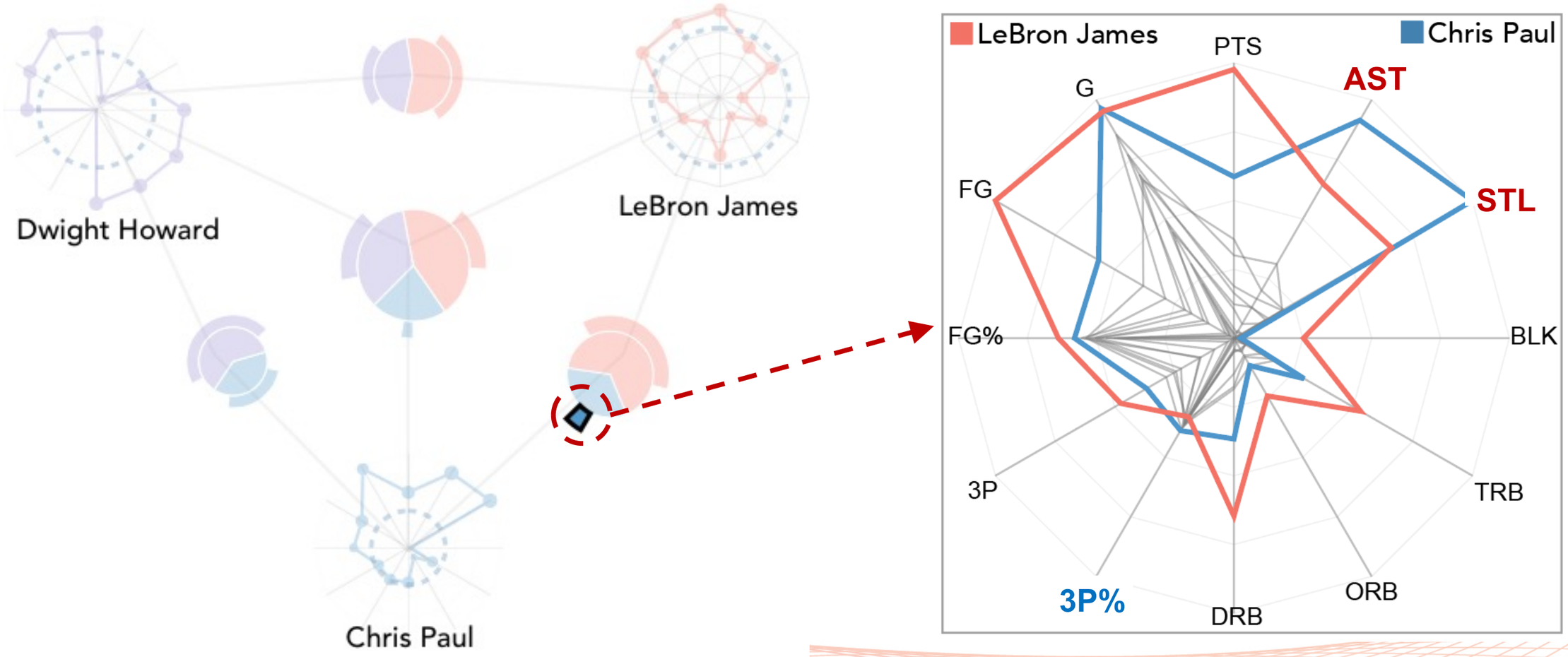
Comparing Dwight, LeBron, and Chris in the perspective of domination relation



Dwight and LeBron have similar dominating scores
Chris has a smaller dominating score compared with them

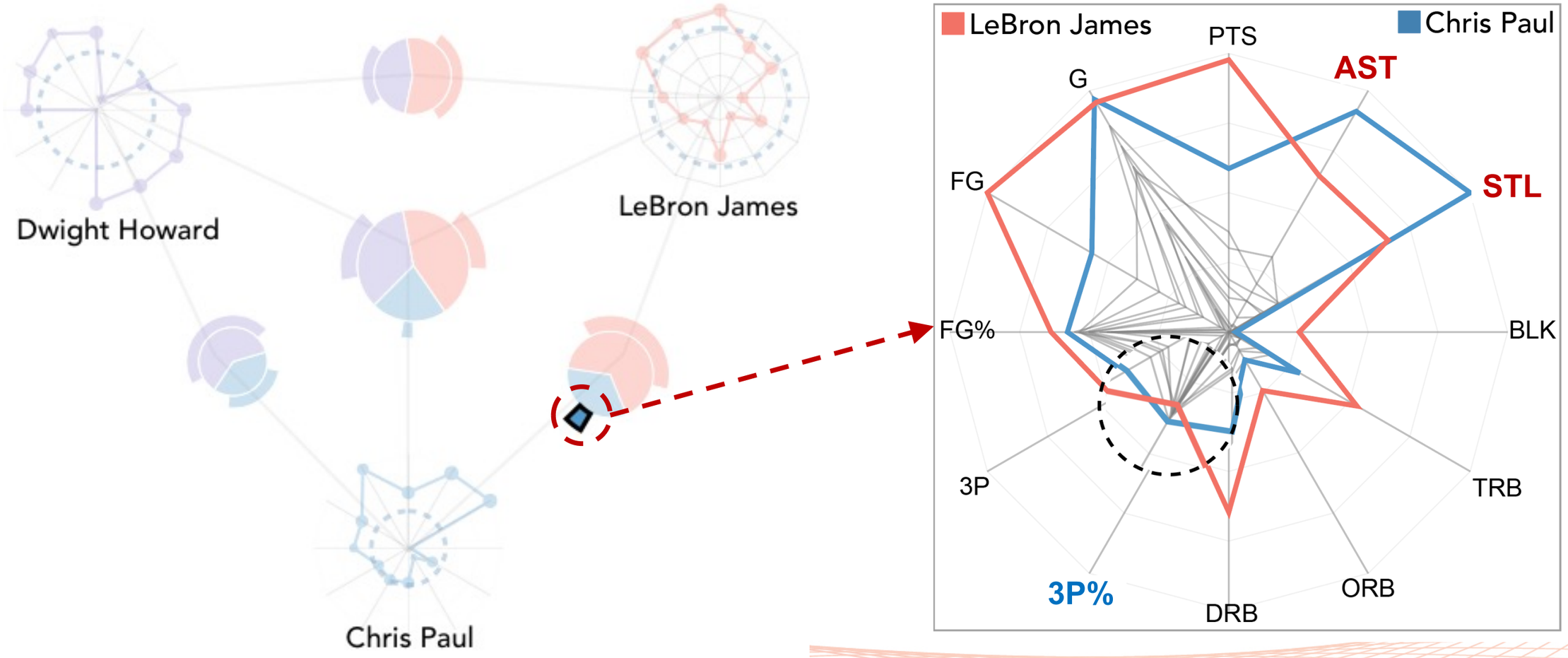
Comparison View – Case Studies

Hovering over the points that are exclusively dominated by Chris against LeBron



Comparison View – Case Studies

Hovering over the points that are exclusively dominated by Chris against LeBron



Evaluation – Case Studies

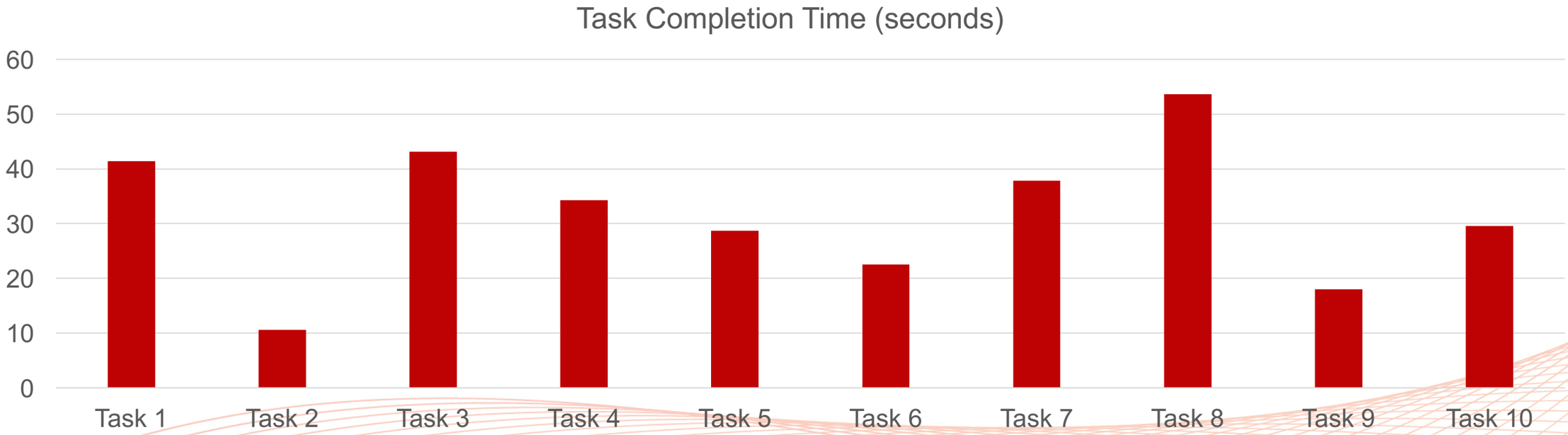
- Two case studies using the NBA and Numbeo quality-of-life data

- NBA 2010 - 2011 regular season statistics
  - 452 players and 12 numerical attributes

- Numbeo quality-of-life data
  - 176 cities and 8 numerical attributes

Evaluation – User Study

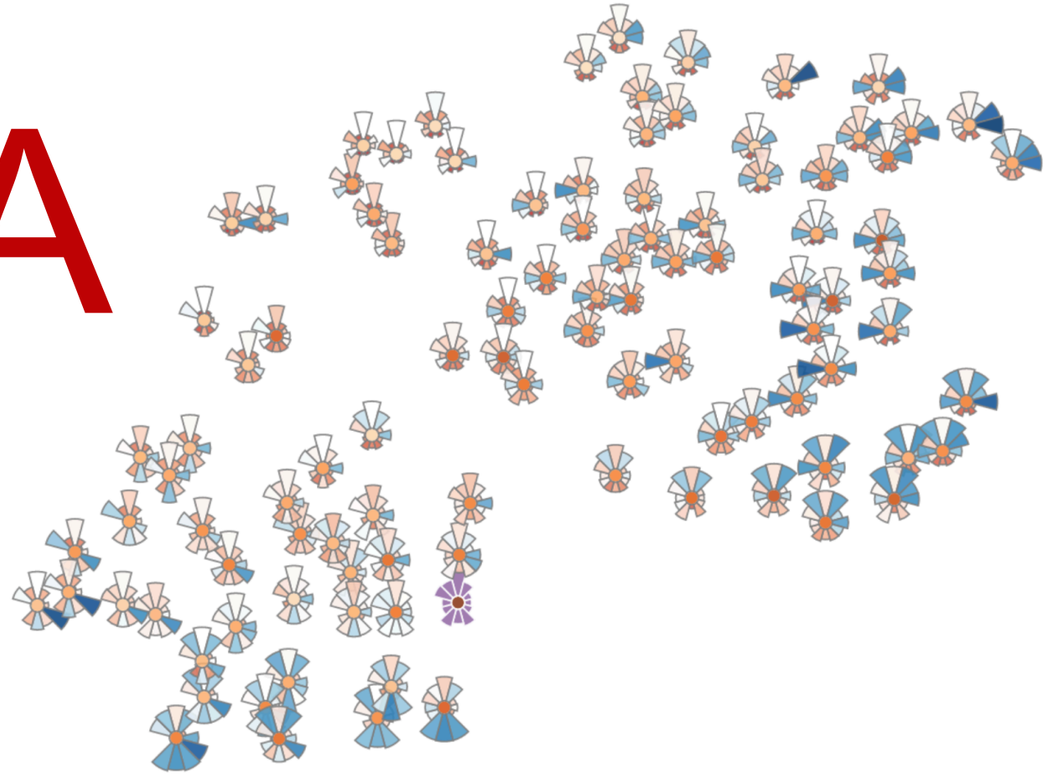
- Qualitative user study
  - 12 participants recruited from the local university
  - 10 tasks covering all important aspects in skyline analysis
  - 19 questions related with SkyLens usage in a post-session interview

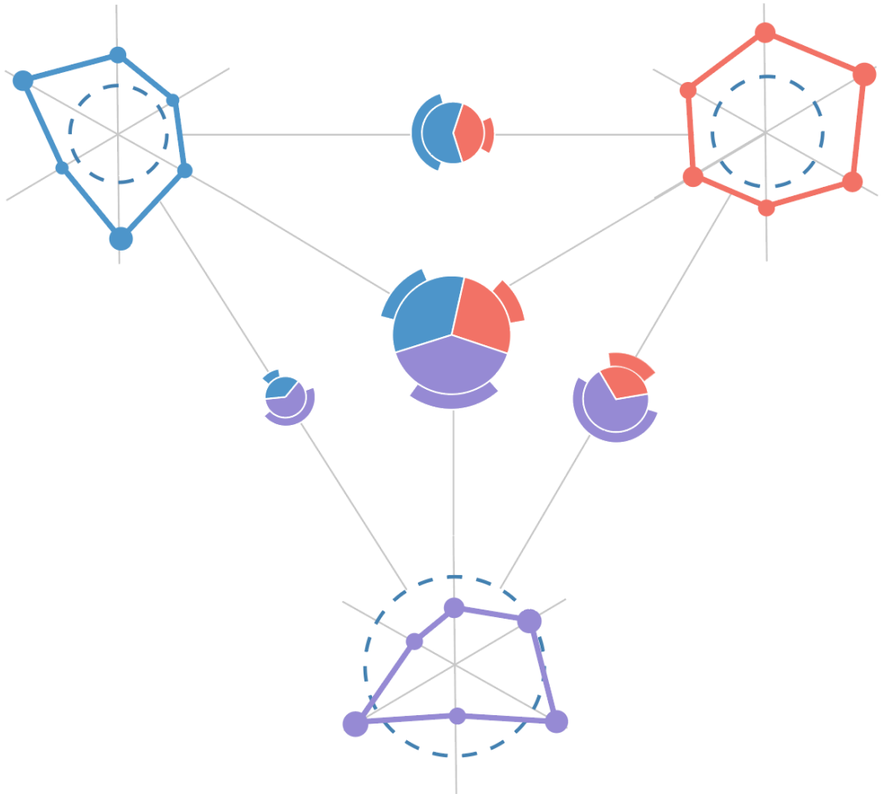


Future Work

- Include nominal attribute analysis
- Support data with uncertain values
- Track temporal changes of skyline

Q&A





香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Microsoft Research
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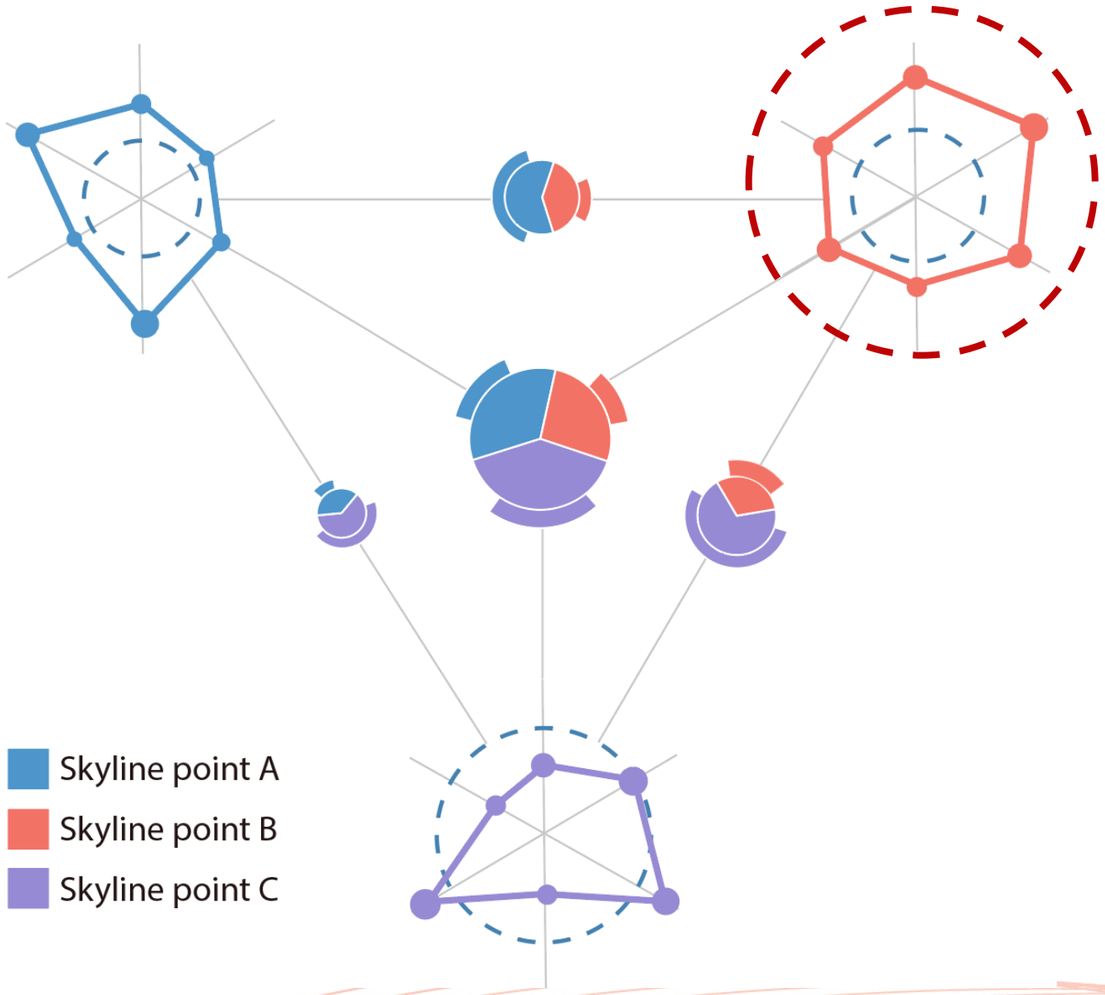
SkyLens: Visual Analysis of Skyline on Multi-dimensional Data

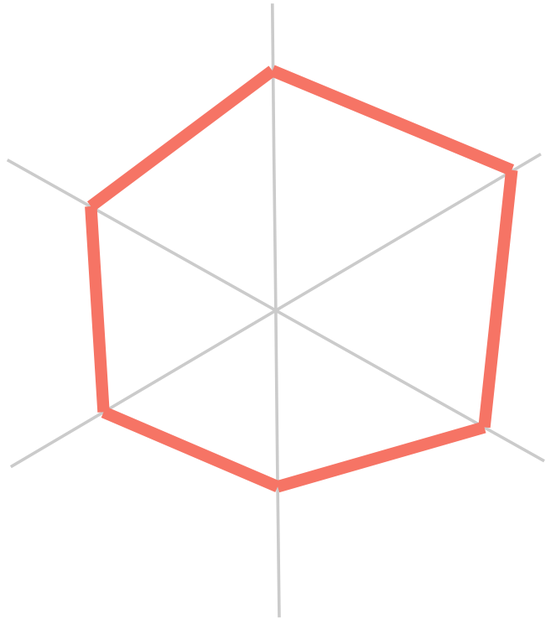
Xun Zhao
Contact: xzhaoag@ust.hk
Project page: http://zhaoxun.me/skylens

Agenda

- Background
- Introduction
- SkyLens
  - Projection View
  - Tabular View
  - Comparison View
- Evaluation
- Future Work

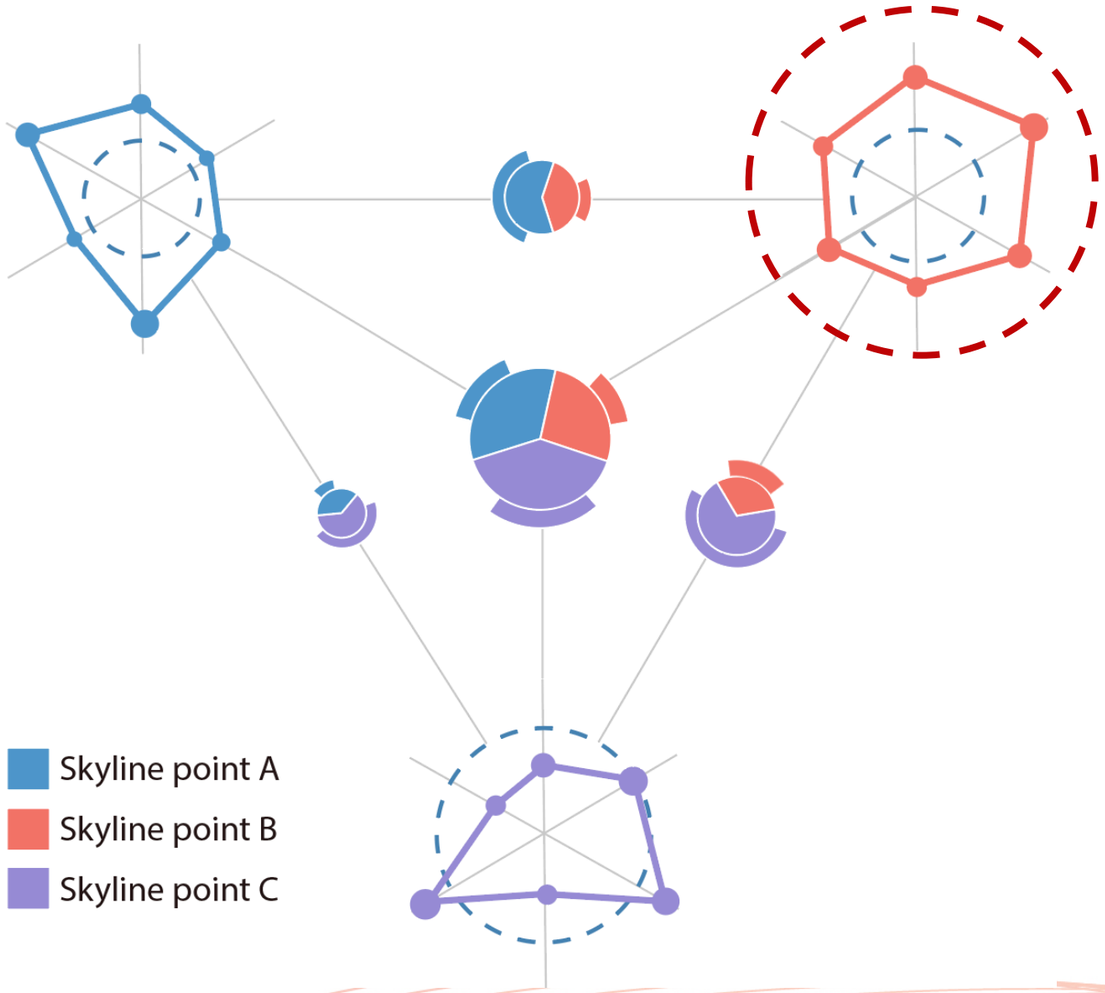
Comparison View – Radar charts

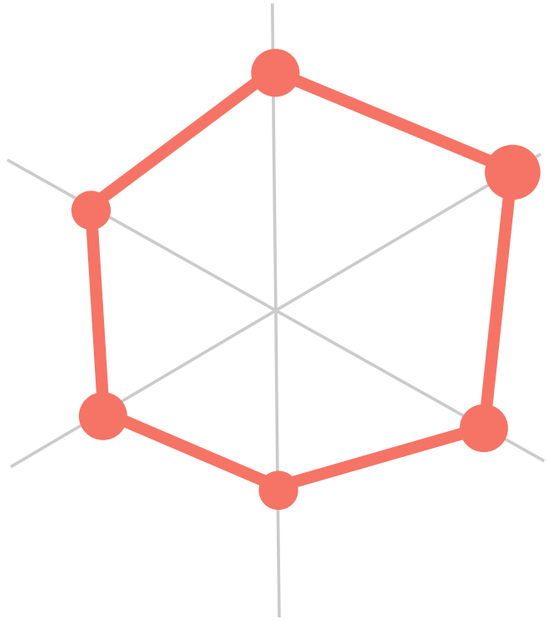




Attribute value: radar chart

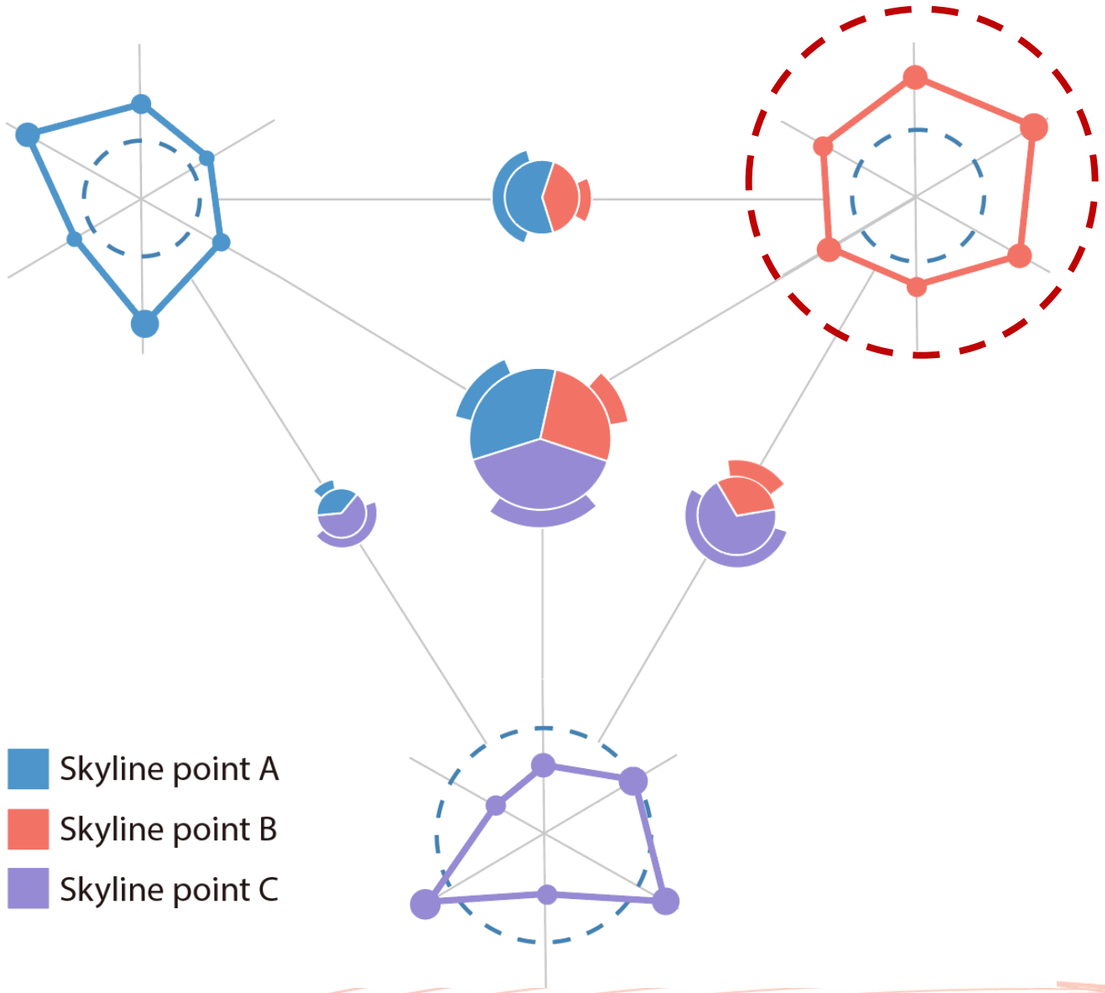
Comparison View

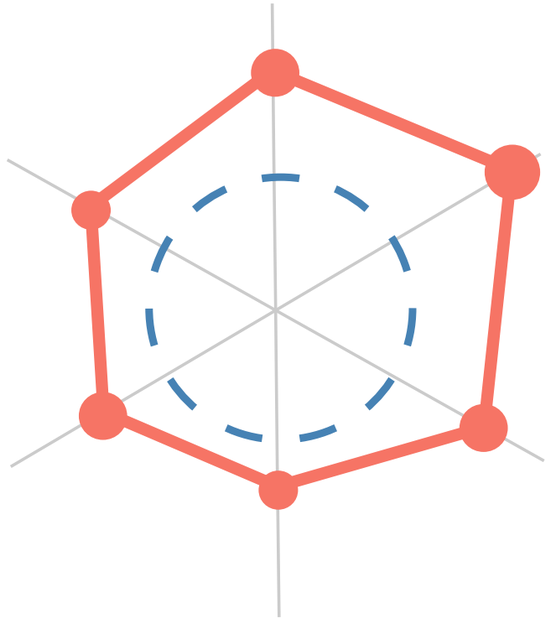




Ranking on each attribute:
radius of circle on axis

Comparison View





Dominating score: radius of dashed circles