Why did they win? Visualizing NBA teams across multiple seasons

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ABSTRACT
Visualization of sports data is very common in recent years as access to this kind of data has increased. The abundance of data and audience allows for new and innovative presentations. In this paper we describe an interactive visualization of the NBA competition over the last 30 years. With three different views, we allow the user to explore data about NBA seasons including standings, team statistics, transfers and player statistics. The d3.js framework was used to develop this visualization.

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H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous;

Author Keywords
Information Visualization; CHI; NBA; D3.js

INTRODUCTION
The National Basketball Association (NBA) [9] is the most famous professional basketball league in the world. As in every other sports branch these days, a lot of data and statistics about players, teams, games and seasons are available, mainly in large tables. Despite the large amount of data available, gathering useful insights from this data can be surprisingly challenging. In our visualization we try to present this data in an innovative but still intuitive way, allowing the user to overcome this challenge and to draw meaningful conclusions.

In this paper we elaborate on the creation and operation of the visualization. The section Goal and Target Audience describes the goal of the visualization and the target audience. In the section Data, the data used, including its origins, advantages and limitations are described. The section Related Work gives an overview of related literature and web resources, including related visualizations. This includes both visualizations of NBA or other sports data, as well as visualizations tackling an issue encountered during the development of our visualization. In the section Visualization, the visualization itself is described. We give an overview of the different stages of development of the visualization, as well as the major design decisions. The section Lessons learned describes some interesting lessons we have learned from the project and in the section Future work we discuss potential improvements of the final visualization. We reflect on our work in the section Conclusion. Appendix A contains definitions for common basketball terms used in this paper. The visualization can be consulted on tankske.github.io/InfoVisNBA/.

GOAL AND TARGET AUDIENCE
The visualization's goal is to answer the following question: "Why did a certain team win the NBA Championship?" The visualization focuses on exposing relations between team performance and their player selection over several seasons. It allows users to find explanations for major improvements and declines in team performance. The visualization allows exploration of NBA data by lay persons. More specifically, the visualization does not focus on premade explanations for phenomena visible in the NBA data. By providing easy and intuitive access to the data, the visualization allows users to draw their own conclusions. Specifically, basketball fans are the core of our target audience. It can be of particular interest with the recent surge in fantasy leagues, a type of online game where participants assemble imaginary or virtual teams of real players of a professional sport, for which data analysis is paramount to a player's success [14, 20].

DATA
The data visualized is a subset of the data available on basketball statistics site basketball-reference [24]. It is a wide range of data including common basketball performance statistics, such as field goals, percentage of shots scored, shooting distance, minutes played per season, number of personal fouls made, salaries and much more. All of this data is available as time-series. These statistics are available for each player individually for each season. Aggregated data for entire teams and for entire seasons is also available. Additionally, individual game statistics are available, including playoff games. In our visualization we only use data from 1984 onwards. This is done because of rule changes in the NBA, which changed the number of teams competing and the competition's structure. To simplify implementation of our visualization, only data after the last major rule change was used. The data we use includes league standings and playoff rankings for each team, team overall statistics, the team's roster and individual player statistics for each year, including the Player Efficiency Rating (PER) [11].

The data was gathered by scraping the basketball-reference site using the provided download capabilities. Most of the data was downloaded in csv format, while some tables had to be scraped manually. This process was automated using Python scripts. The data was then combined in a preprocessing step. In this step, each team's play-off rankings were calculated based on the matches played during the play-offs, and the rest of the data was combined into json format. The final

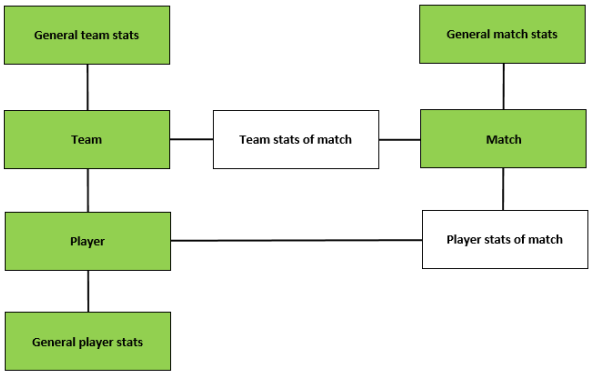

Figure 1. An overview of the data.

preprocessing step combined all data into one json file. A model of the available data can be seen in Figure 1.

RELATED WORK

Recently, there has been an increase in the interest in visualizations of sports data. This is best exemplified by the workshop on sports data visualization at the IEEE Visualization Conference in 2013 [17].

There are a number of traditional basketball visualizations, with the shot chart being one of the most popular. A shot chart visualizes the shots made by a player or team. Different methods can be used, going from a scatterplot to hexagonal charts where the shots are grouped into hexagonal regions, to a heatmap. This is often done for the area in and around the three-point line, but it can also be done for the whole attack side of the field, as seen in the visualization of Vorped [29]. Because shots of the own side only happen rarely, it's usually not shown in shot charts. Shot chart provides insight into the shooting ability of a player [16, 6].

This view features heavily in Peter Beshai's Buckets [2]. This is an extensive visualization of NBA player data. It provides not only the player's shot chart for various years, but his shooting signature and several line graphs as well. It is strongly focused on individual player's shooting abilities.

Visualizations focusing on basketball teams and their performance are less common to find. For the play-offs, there is the traditional tournament bracket structure [23]. This bracket structure has the advantage of being well known and as such, does not require much explanation. However, it duplicates much information by displaying teams repeatedly.

An interesting alternative is the sunburst tournament visualization [22]. As the name suggests, this visualizes the tournament as a sunburst, with the winning team taking the part of the circle closer to the center. This kind of visualization has the same drawback as the traditional bracket structure has.

Peter Cook created the Player Bubbles visualization [12], where the tennis tournament Wimbledon is visualized as enclosed circles. A player is represented by a bubble that encloses all the bubbles of players he has won of. This eliminates the need of repeating the same player twice, but on the other hand it uses a lot of space and it makes it hard to understand the structure of the tournament.

In the Guardian, the England's Premier League results were visualized by Ami Sedghi [25]. This visualization shows the team's rankings as line graphs and allows highlighting of individual teams.

Tan et al. created an adaptation of the traditional tournament bracket to better support modern interaction [27]. The tool, AdaptiviTree, changes the brackets shape and adds colored lines to show available information as the user picks his own bracket.

An alternative to the traditional bracket structure can be found in the visualization of the race to the white house in 2012 made for the New York Times by Mike Bostock and Shan Carter [4]. They use a tree-like structure where each split represents a state being one by one candidate or the other. The interactivity is very important here as it allows users to highlight one possible path out of many. The play-off view in our visualization is inspired on this visualization as explained in the section Visualization.

The entire history of the NBA and the best teams were analyzed by fivethirtyeight [15]. They calculated an ELO-score [7] for all teams and visualized them on line graphs.

In the article written by Johannes Becker [1], the Simple Rating System score (SRS score) is used to compare teams over the last 40 seasons in the NBA. The SRS score is represented by a color hue. For comparing quantative values, this is not the most ideal characteristic to use as explained by Jock Mackinglay [19]. Nevertheless, some interesting insights are found and presented. By giving a green stroke to the rectangle of the champion of a season, it's easy to see which teams have won the NBA championship frequently. This way they have divided the last 40 seasons in three eras being the Los Angeles Lakers versus the Boston Celtics era, the Michael Jordan era and the Tim Duncan era.

Pagno et al. provide a number of different visualizations [21], with the starplot being one of the most interesting. It plots several statistics for a team on an axis pointing radially outward from a common center. These points are then connected. It allows the user to get basic information about a team or player at a glance. Because of this speed of conveying information, it is also a prevalent visualization in sports games.

VISUALIZATION

The visualization consists of three parts:

- The play-off view: a compact view on the play-offs per season
- The statistics (zoom) view: a more detailed view on a statistic of a selected team
- The team view: a detailed view on how good or bad a team scores on a specific field position

The technique used, follows the standards of information visualization. It provides an overview, allows zooming and

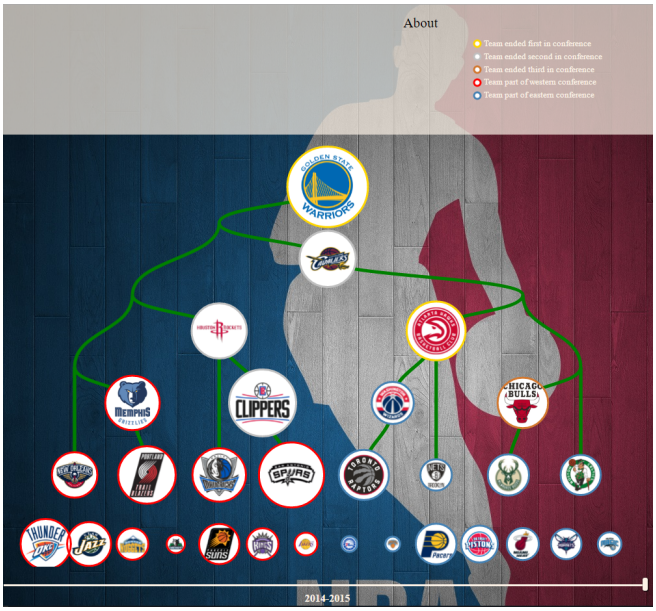

Figure 2. The play-off view without a team selected.

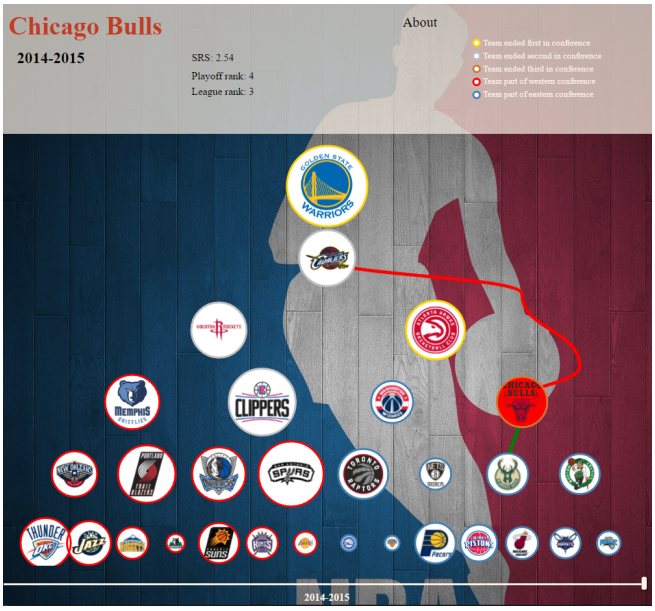

Figure 3. The play-off view with a team selected.

filtering and provides details on demand [26, 30]. The play-off view provides the full overview which allows filtering by team. The statistics view provides the ability to zoom in on one specific team. There some details are provided instantly, while others can be procured by hovering over certain elements.

All three views are discussed in more detail below. The three views are available to the user on a single webpage, where they are organized in a vertical layout with fixed scrolling. The user start on the play-off view. Navigation with the keyboard for switching between the three different views is supported as well, with standard browser navigation by pressing the space bar or the up-and-down arrows. A different season can be selected with the left and right arrows or by clicking on the timeline. The timeline is a fixed part of the visualization. It is visible in the three different views.

We did not opt for the traditional minimalistic approach used in information visualizations. The data-ink design principles were kept in mind, but we also focused on aesthetics instead of maximizing the data-ink ratio. So the choice was made to use a thematic background. This was done to improve the attractiveness of the visualization on the one hand and the users' memory of it on the other hand [28].

The play-off view

This view informs the user of the roster and end positions in the NBA play-offs for a selected season, in general or for a selected team. The play-off view is shown in Figure 2. The view consists of two parts:

- Context section: the top part informs the user about the selected team and shows a legend of the play-off view.
- Bubble section: this section represents the play-offs of the selected season.

Context section

The context section contains a legend for the bubble section. The bubble's borders are gold, silver or bronze if the team ended respectively first, second or third in the regular competition. Teams that didn't end on a podium place during the regular competition have a red or blue stroke color indicating the team's region, respectively the western or eastern conference. The context section also contains a link to the "About" page where the user can get an explanation of the visualization with its different views, some background information about the NBA and the terminology used, and the link to the source of the data used in the visualization. If the user hovers over or selects a team in the bubble section, the context section shows more information about that team, as shown in Figure 3. The information shown includes the SRS score, the end position in the play-offs and the end position in the regular competition.

Bubble section

This section presents the roster and end positions of the play-offs for a selected season. Every team is represented by a circle with the team's logo inside it. The size of the circle represents the SRS score using an own interpretation of perceptual scaling because the (Flannery) Appearance Compensation is not usable with a domain of both negative and positive values. An exponential function with exponent 1.5 was used. This way the proportion between the area of a bigger and a smaller circle will be greater than the proportion of values the areas represent to improve human perception.

The curved lines between teams represent the fact that those teams have encountered each other in the play-offs. Each row represents an end position in the play-offs. The higher a team stands, the further it has come. From the top to the bottom, the rows represent the winner of the final (rank 1), loser of the final (rank 2), losers of the semi-finals (rank 3), losers of the quarter-finals (rank 4), losers of the first round in the play-offs

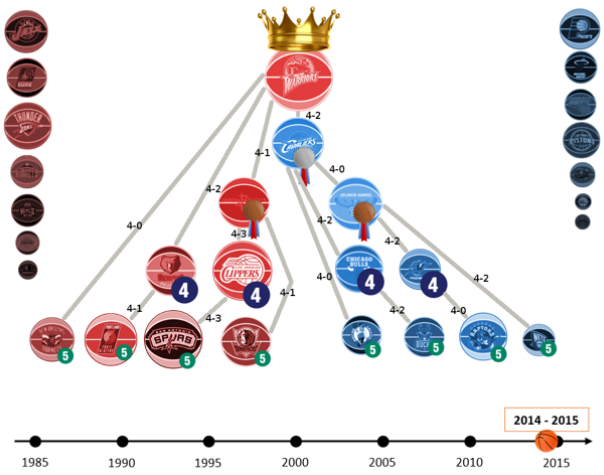

Figure 4. First design of the play-off view.

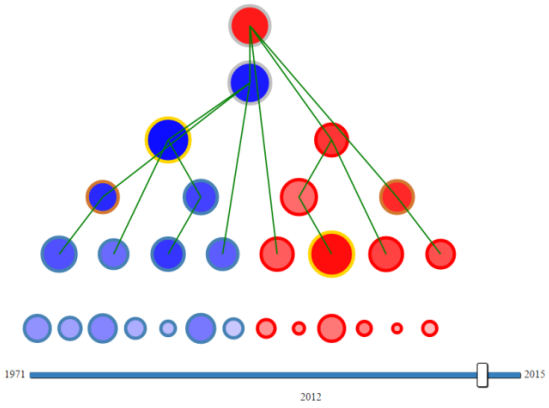

Figure 5. First implementation of the play-off view.

(rank 5). The last row represents the teams that did not make it to the play-offs (rank 6).

This simple presentation intuitively puts the winning teams higher than the losing teams. The winner and loser of a certain game can be easily derived from their relative vertical position. It is also clear that for a team to be on a higher level, the team needs to have played and won a series of matches against one other team at every level below them, which can be seen in Figure 2. This view is further reinforced by highlighting a team, its matches and opponents when hovering over it. To emphasize the matches won and lost, the colors green and red where used. Additional team information is also shown in the context part when hovering over a team.

Previous designs

Our initial design used the team circles' lightness to indicate their final ranking in their region. The hue was red or blue indicating the teams' region. According to the Ranking of Perceptual Tasks by Jock Mackinlay [19] this is a good property for ordered values like the end positions in the regular

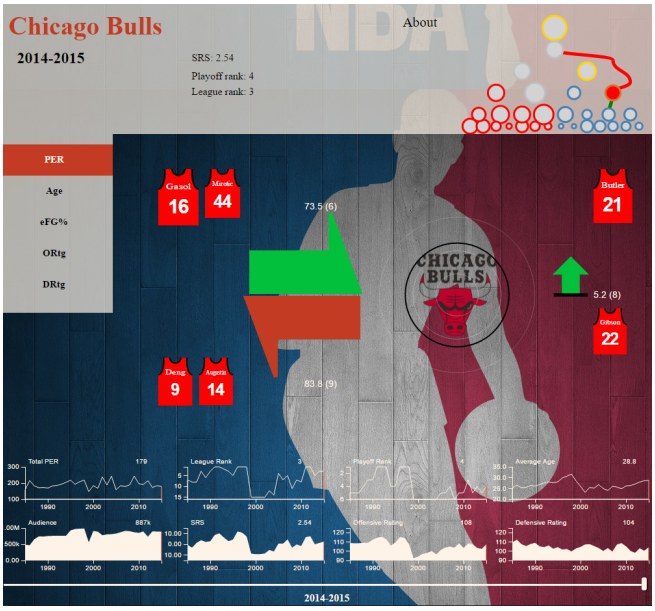

Figure 6. The statistics view.

competition ranking. But the combination of the teams' logo's with the different hues and ligthnesses resulted in an overload of information and made it more difficult to compare different teams based on their end ranking. Our initial design is shown in Figure 4.

As an alternative we tried the same view without the logo's, as shown in Figure 5. This turned out to be inconvenient for the user as one could not instantly see which team is represented by which circle. Recognizing the different teams is a fundamental part of our visualization, while the comparison of end ranking of different teams would not have great importance. Therefore we've chosen to only use the teams' logos.

Our initial play-off view was too dense because teams that played against each other were connected directly. This can also be seen in Figure 5. When searching for alternatives to reflect on our choice we discovered a similar visualization by Mike Bostock and Shan Carter [4] in a totally different context as explained in the section Related Work. With the idea of this visualization in mind, our visualization gives a cleaner view of the competitors for a specific team compared to our original sketch. Hence we decided to adapt our visualization.

We initially also considered a map view to show the teams and their regular competition ranking on a map of the USA. However, the geographical position gave no additional information that would contribute to meaningful insights. Furthermore we've found a visualization of the NBA with a map view made by Leeman Chiu [5] similar to our idea, so we decided to not implement this map view.

The statistics view

The statistics view gives a user a clear overview of how a statistic has been influenced in the selected season compared

to the season before. The statistics view is shown in Figure 6. The view consists of 3 coordinated parts:

- Context section: the top part informs the user of the context of the selected team
- Arrow section: this section illustrates how transfers change statistics compared to the previous season
- Selected statistics section: team statistics and how they evolve over time

Context section

The context section is partly identical to that of the play-off's view. The team's information is again displayed in the top left. In the top right, the bubble section of the play-offs view is displayed in a reduced, minimalistic form. This view is repeated to create a sense of continuity between the different views and to provide context of the current position in the visualization. The team shown in the statistics view is highlighted on this smaller bubble section the same way as in the large play-off view.. Furthermore, replicating this section alleviates short-term memory limitations. It prevents the need to scroll back and forth between the different views constantly.

Arrow section

This section illustrates how transfers change a chosen statistic for the selected team in the selected season compared to the previous season. This gives a user more insight into why a statistic changed over time and how this change has affected team performance. The selected team is represented by a circle in the same way as in the play-off view. To give the user a better interpretation of the SRS value of the team, three other reference circles are drawn. These are transparent with a lightgrey border and show the maximum, average and minimum SRS value of the NBA teams in the selected season. The change for the chosen statistic is represented by three arrows:

- Arrow on the left pointing towards the circle: indicating the influence of players who joined the team
- Arrow on the right of the circle: indicating how the team internally changed, e.g. by training its players
- Arrow on the left pointing away from the circle: indicating the influence of players who left the team

The value of the change in statistic is shown next to the arrow, as well as the number of players responsible for the change, which is shown between brackets. There are maximum two jerseys next to the arrows as well. These are the jerseys of the players that had the biggest contribution to the change represented by their corresponding arrow. On the left, there is the possibility to choose a statistic. The different possibilities are the PER value, the age, the effective field goal percentage, the offensive rating and the defensive rating. Below this menu, player information is shown when a user hovers over a player's jersey.

Selected statistics section

Below the arrow section, multiple line and area charts show how the selected team has performed over the years. The different statistics shown are the total PER of the whole team,

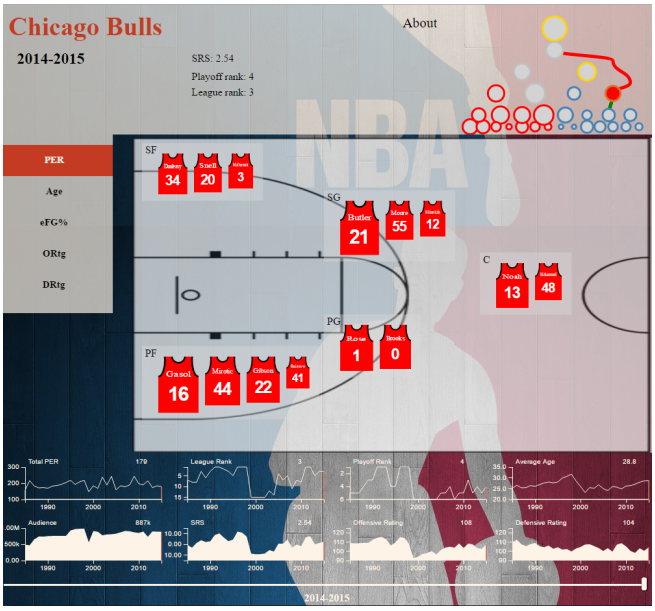

Figure 7. The team view.

the league rank, the play-off rank, the average age of the team, the audience, the SRS-value of the team, the offensive rating and the defensive rating of the team. A user interacts with the visualization by shifting the bar indicating the current year displayed or the timeline. By doing this the view gets updated and the user can see the impact on the team in the context section and why the statistic changes in the arrow section. These charts enable the user to identify peaks or drops in a certain team statistic. By interacting with the visualization, previous seasons can be inspected to try and find explanations. The user could also look at the following seasons to see how a team performed related to the evolution of a statistic. This view provides a lot of additional information to users by allowing them to see correlations between statistics and phenomena quickly and easily.

Previous designs

This view has not changed much compared to the initial design. The only difference is the position of the arrow and jerseys for the players who stayed, which was originally located in the team circle, and so the team's logo was not shown. The design of the arrows did not change. The incoming and outgoing arrows are maybe more intuitively than the arrow for the stayed players, but we did not find any alternatives we could use.

The team view

The team view gives a user a detailed view on the strength of the team at the different field positions. The team view is shown in Figure 7. The view consists of 3 coordinated parts:

- Context section: the top part informs the user of the context of the selected team
- Field section: this section illustrates the strength of the whole team on the different field positions
- Selected statistics section: team statistics and how they evolve over time

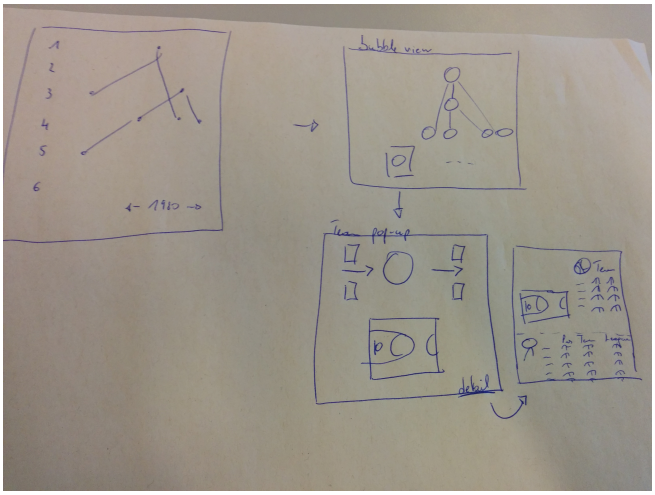

Figure 8. A sketch of a previous design including the small multiples on the bottom right.

The context section and the selected statistics section are fixed parts in the statistics and team view, and are therefore not explained again for this view.

Field section

This view shows each player of the team at its field position. Players are represented by their jerseys. Jerseys aligned next to each other share the same position, which is indicated with a rectangle. The size of a jersey illustrates a player's performance according to the chosen statistic. The possible statistics are shown on the left and are the same as those in the arrow section of the statistics view. As well as the statistics view, this view should give the user the ability to search for explanations why a team is performing better or worse over seasons. On the other hand, a user can see what impact a change in team characteristics has on its overall performance. This view should give a user insight on how strong or weak a particular team is for a specific field position. A user can then scroll through time to see how field positions evolve and what the influence of this field changes are over time.

Previous designs

Initially we designed this view more elaborate. When the user would click on a jersey, specific player information would be shown together with a number of player statistics in the form of small multiples. A bell curve should have informed how a player scores compared to his team, other players in the league on his position or all other players in the league. We considered other charts for the small multiples as well. A box plot or bullet was less clear for us to indicate where a player stands compared to the group he was compared with. This part of the visualization was not our main focus. Because of the lesser importance and because of time and resource constraints, it has not been developed. A sketch including the small multiples view on the bottom right is shown in Figure 8.

Technology

To create the visualization, the d3 javascript framework [3] was used in combination with html5 [8] and jquery [18]. Note that D3 is based on HTML, CSS, Javascript and SVG. This allows easy access to the visualization as most modern browsers are capable of handling these webstandards. The choice not to use the d3 framework for the entire visualization was made to ease the layout configuration of the visualization. Instead, html was used to do the global layout of the visualization. We opted to structure the site with multiple divs as containers. To each container we allocate an svg with a specific visualization.

When working with d3.js we encountered one main obstacle:

- Asynchronous calls had to be combined with synchronous calls. More specific, when a visitor uses the timeline to scroll through time, the wiping of previous visualizations was not synced with the creation of the new visualization. This resulted in wiping sections when a visualization was not created yet. Hence the view resulted in multiple figures overlapping.

LESSONS LEARNED

We've learned a couple of things during the creation of this visualization:

- Find a story to tell with your visualization
- Each separate component should be a sufficient informative visualization on itself
- Creating a custom visualization costs time and opportunities

In what follows we will discuss our experience in more detail.

Story telling

At the beginning of this project we were able to design the 3 separate views quite quickly. Our main concern was to integrate these views as a whole and to be able to let a user see relations between the teams' performance and their statistics to draw conclusions of his/her own. The relation we thought would be visible was that the total PER value of a team would influence the end positions in the NBA championship, both the league rank as the play-off rank. We expected that teams that had a big increase in total PER value, due to a good transfer policy during a season, would benefit from it in one of the following seasons. We were not able to conclude this from the data as some players may play a lot more than others and are therefore of much bigger importance for the team. This interesting observation led us to a story about the Chicago Bulls, the team of Michael Jordan, who is considered to be the greatest basketball player of all time. In 1984, Jordan arrives at the Chicago Bulls and in his first season he is already the top player of his team, as seen by the size of his jersey for the PER statistic. In the season 1990-1991 and the two following seasons, the Chicago Bulls win the NBA championship. The "three-peat" as it is called, was done with almost the same core team. Next to Michael Jordan, there were around five players that were part of the team and were roughly the best on their position in the team, for example Scottie Pippen. We can see that in the seasons before this "three-peat" this team was formed and already played with each other. After that last season from those three consecutive wins, Michael Jordan retires and the team failed in winning the NBA championship again. In the middle of the season 1994-1995, Michael Jordan came out of retirement. What follows is a similar story to

the previous one. In the season 1995-1996 and the two following seasons, the Chicago Bulls again achieve to win the NBA championship three times in a row, again with a team consisting of around five core players. Once again is Michael Jordan the star player of the team, but also Scottie Pippen is still one of the best players of the team. So it seems that to become the champion, a team needs to have a default team with around five core players from which one or two are star players. By having this story it was easier for us to evaluate our design. We could focus more on important parts of the visualization and cut less relevant parts from the project, e.g. the detailed player information.

Each component should be informative

In order to have a good visualization as a whole, each component should be a clear and informative visualization on itself. During the project, we started noticing that most components in a visualization lack references and hence are not informative enough, e.g. each small multiple of a statistic in the statistics view gives sufficient information to stand on itself. The bar in the small multiple indicates the score in the selected season and enables the user to evaluate that score over time. Have there been better scores, or worse scores? Is this score part of an upward movement during years? This should be weighted against the duplication of data and the use of screen space. Coordinated views alleviate this need significantly, as each component is strongly supported by other components.

Custom visualizations

Before exploring what is out there in the d3.js world, we made our own sketches. This is how we came up with the three custom views that make up our visualization. When comparing our design with alternatives we could not find something that satisfied our needs. Nonetheless, they gave us inspiration to fine-tune our design. Although we are satisfied with our result and we are convinced it was the right choice to reach our goal, it had some drawbacks. If we did not started with our custom view, we would have had more freedom in exploring multiple different visualizations and we would be able to evaluate different options with trial and error. Instead much of the developing time was spent on the technical details for these custom visualizations. This was especially true for the bubble component of the play-off view. No out of the box solution for this could be found so everything from the determination of the positions of the bubbles to how to connect them we had to develop ourselves.

FUTURE WORK

As with most projects, the result is never 'finished', meaning that there are always extensions and improvements possible. We suggest a number of features that might improve the visualization:

- Smooth/animated transitions between states could improve the user experience. For example when changing seasons, an animated transition of the arrow in the statistics view would help the user see the difference between the seasons. At the moment the arrows change at the blink of an eye, making it difficult for us, humans with a short term memory, to make the comparison. This would also have been very useful in the transitions between different years on the bubble view.
- To further support our short term memory we could also 'save' the previous state. E.g. in the field view we could visualize ghost jerseys to indicate which players left the team or position and highlight players that joined the team. This would help the user see how the team changes over time.
- At the moment no attention has been payed to the process, provenance and history of the user's exploration session. A user needs to memorize his action to be able to share or reproduce his actions. This could be improved by adding URL parameters. This way a user can share or save a state of an analysis. One step further is to provide a play-feature. Then the visitor could share his exploration and replay it. A simple implementation would ask the visitor for a start date and an end date and would then 'play' the changes of the selected team and characteristic.
- We could support users further in looking for patterns by focusing more on comparisons. We could integrate a view where a visitor is able to compare two teams in the same year or in two different years, for example by duplicating current views next to each other.
- We could focus more on the core team, i.e. five or six players who seems to be the most important for the results of a team.
- As mentioned before, we could elaborate more on individual player information and visualize their statistics relevant to their field position.

CONCLUSION

We believe the visualization can be of tremendous value for fans of the NBA and fantasy basketball players. Personally we have gained several insights into the performance of basketball teams by using the visualization and we believe others could learn even more. The most interesting conclusion we were able to make concerns the importance of individual players in a basketball team. We were able to find strong correlations between having two to five very strong players and the team's performance. It seems that just having one star player is not enough. On the other hand, having more than 5 good players no longer has much influence either.

While the visualization has a lot of potential for improvement, we think the innovative play-offs representation combined with detailed team information in an integrated fashion enables users to gain insights into why certain teams won the NBA Championship.

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APPENDIX

TERMINOLOGY

PER

Player Efficiency Rating - An all-in-one basketball rating, boiling down all of a player's contributions into one number [11].

SRS

Simple Rating System - a rating that takes into account average point differential and strength of schedule. The rating is denominated in points above/below average, where zero is average [13].

Play-offs

The National Basketball Association (NBA) play-offs are a best-of-seven elimination tournament among 16 teams in the Eastern Conference and Western Conference, ultimately deciding the winner of the NBA Finals [10].

Jersey

The shirt worn by basketball players.

Three-point line

The line that separates the two-point area and the three-point area.