Why did they win?
Visualizing NBA teams across multiple seasons

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Abstracts should be about 150 words

ABSTRACT
Visualization of sports data is very common in recent years as access to 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.

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

Author Keywords
Information Visualization; CHI; NBA

INTRODUCTION
The National Basketball Association (NBA) is the most famous professional basketball league in the world**nbawiki**. As in every other sports branch, 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 work we try to present this data in an innovative but still intuitive way, allowing the user to draw meaningful conclusions.

In the Goal and Target Audience section we describe the goal of the visualization and the target audience. In the Data section, we describe the data used, including its origins, advantages and limitations. The Related Work section 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 Visualization section, 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 Lessons learned section describes some interesting lessons we have learned from the project and in the Future work section we discuss potential improvements of the final visualization. We conclude in the Conclusion section. Appendix A contains definitions for common basketball terms used in this paper.

GOAL AND TARGET AUDIENCE
The visualization's goal can be best summarized by the following sentence: "Why did a certain team win the NBA Championship?" The visualization focuses on exposing relations between team performance and their player roster over several years. 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 phenomenons visible in the NBA data. By providing easy and intuitive access to the data, the visualization allows users to draw their own conclusions. The visualization's target audience are lay persons. Specifically, basketball fans are the core of our target audience. It can be of particular interest with the recent surge in fantasy leagues, for which data analysis is paramount to a player's success **fantasy**; **fantasyskill**.

DATA
The data visualized is a subset of the data available on basketball statistics site basketball-reference**basketball-reference**. 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 also 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 PER (Player Efficiency Rating)**per**.

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 manually scraped. This process was automated using Python scripts. The data was then combined in a preprocessing step. In this step, each team's playoff rankings were calculated based on the matches played during the playoffs, and the rest of the data was combined into json format. The final

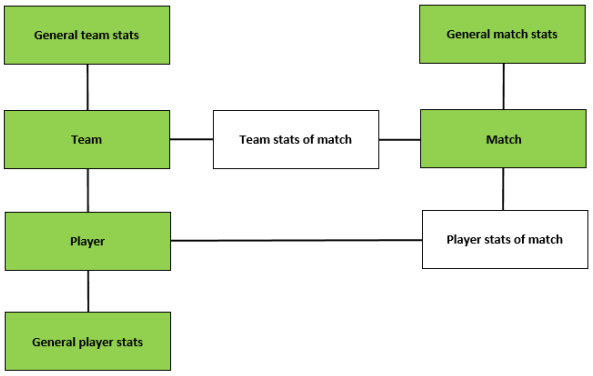

Figure 1. An overview of the data.

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

is die afbeelding nog wel juist? Is die nuttig?

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**ieeevis**.

There are a number of traditional basketball visualizations. One of the most popular ones is the shot chart. This 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 the area in and around the three-point line, but it can als be done for the whole attack side of the field, as seen in the Vorped visualisation**vorped** Because shots of the own side only happen rarely, it's not shown in shot charts. Shot chart provides insight into the shooting ability of a player**goldsberry**; **stephenchu**.

This view features heavily in Peter Beshai's Buckets**peterbeshai**. 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 significantly more difficult to find. For the playoffs, there is the traditional playoffs bracket **tournamentladder**. This bracket structure has the advantage of being well known and as such, not requiring much explanation. It is flawed however. It duplicates much information by displaying teams multiple times.

An interesting alternative is the sunburst tournament visualization**sunburst**. 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 does not eliminate the problem of the recurring teams however.

For the wimbledon tennis tournament, an enclosed circles visualization was created **enclosedcircles**. This visualization eliminates the repeating occurrences of the same team. However, it wastes a lot of space.

England's Permier League results were visualized by Ami Sedghi for the Guardian**premierleague** This visualization shows the team's rankings as line graphs and allows highlighting of individual teams.

Tan et al. created an adaption of the traditional tournament bracket to better support moden interaction**adaptivitree**. 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**whitehousepath**. 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 entire history of the NBA and the best teams were analyzed by fivethirtyeight **fivethirtyeight**. They calculated an ELO-score**eloraring** for all teams an visualized them on line graphs.

In the article written by Johannes Becker**nbaempires** 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 John Mackinglay**automatingdesign**. Nevertheless, some interesting findings 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**starplots**. The most interesting one is the starplot. This plot 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 filtering and provides details on demand**mantra**; **multipleviews**; **automatingdesign**. The play-off view provides the full

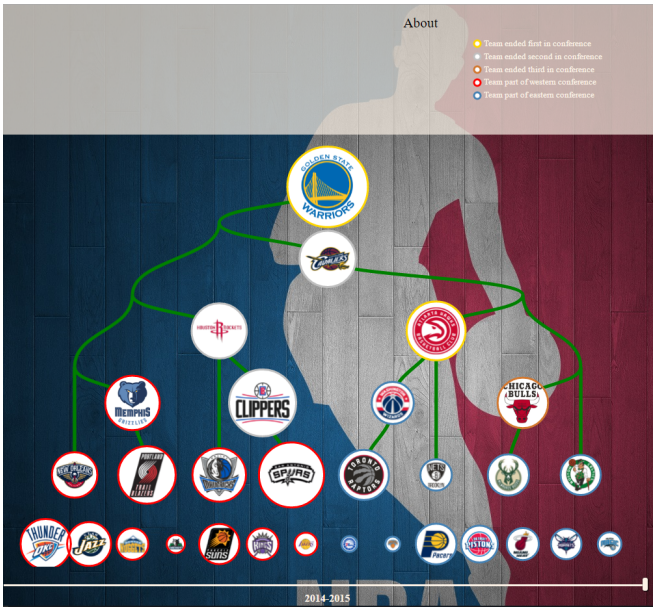

Figure 2. The play-off view without a team selected.

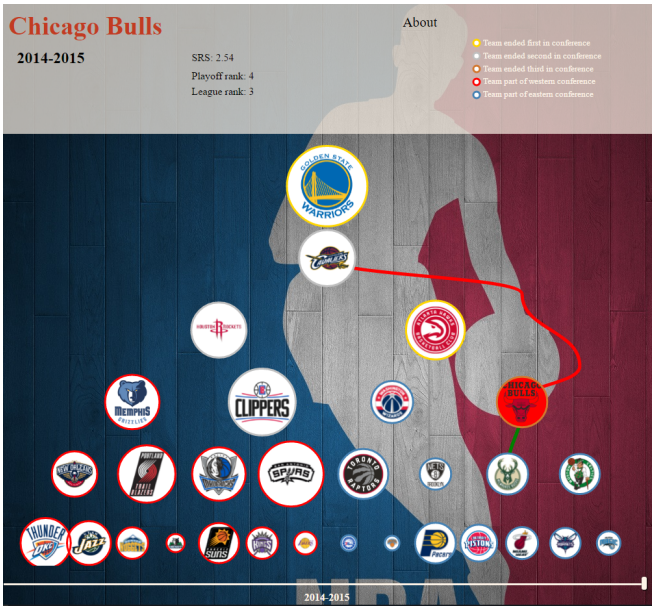

Figure 3. The play-off view with a team selected.

overview which allows filtering by team. The statistics view provides the ability to zoom into 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. Navigation with the keyboard is supported as well. The user start on the play-off view and is able to navigate to the statistics and team views by scrolling down or clicking on teams. 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. Navigation with the keyboard for switching between the three different views is supported as well.

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 visualisation on the one hand and the users' memory of it on the other hand**aesthetics**.

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 **??**.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, can get some background information about the NBA and the terminolgy used, and can check 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 **??**. 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 respresented by a circle with the logo of the team 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 the area of a smaller circle will be greater than the proportion of values the areas represent.

The curved lines between teams represent the fact that those teams have encountered each other in the playoffs. Each row represents an end position in the play-offs. The higher a team is, 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-

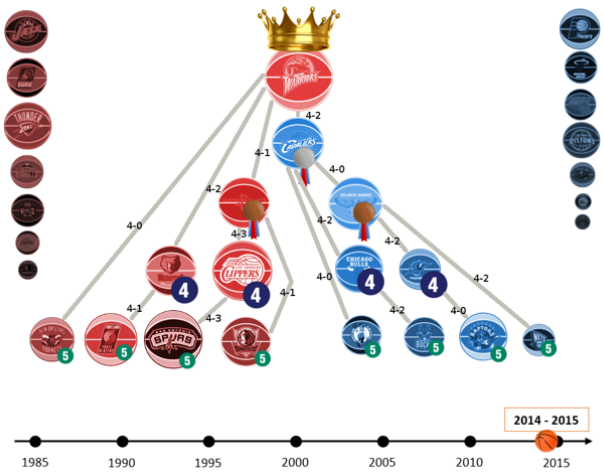

Figure 4. First design of the play-off view.

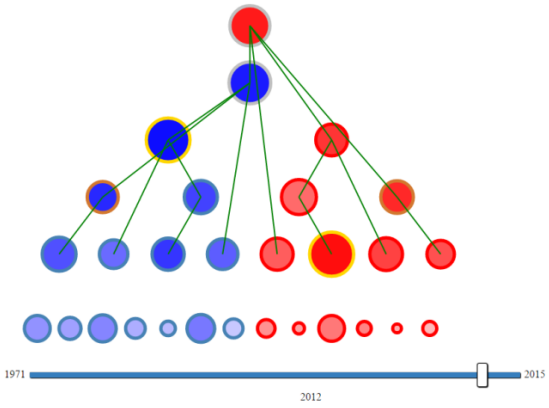

Figure 5. First implementation of the play-off view.

finals (rank 4), losers of the eighth finals (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 **??**. This view is further reinforced by highlighting a team and its matches and opponents when hovering over it. Additional team information is then also shown in the context part.

Previous designs

Our initial design used the team circles' lightness to indicate their final ranking in their region. The hue was used to show the league they were part of. According to the Ranking of Perceptual Tasks **automatingdesign** this is a good property for ordered values like the regular competition ranking. But the combination of the logo's of the teams with the colors resulted

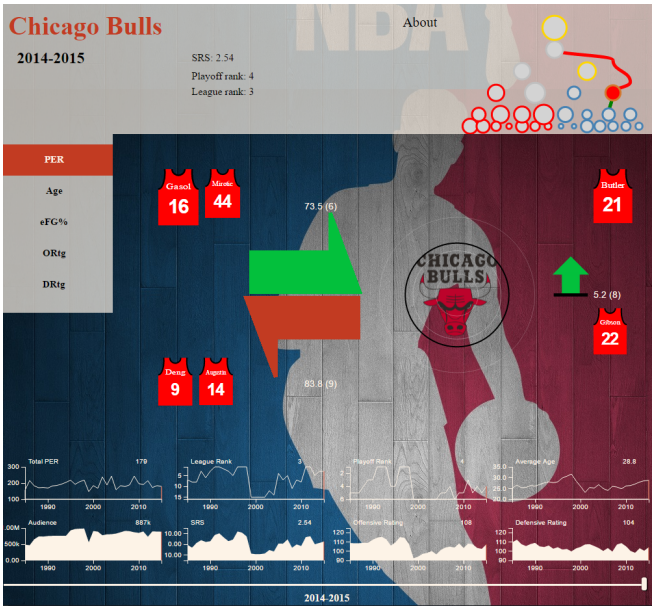

Figure 6. The statistics view.

in an overload of information and made it more difficult to compare the end ranking of different teams.

As an alternative we tried the same view without the logo's. It turned out this was inconvenient because you could not instantly see which team is represented by which circle. Therefore we've chosen to only use the teams' logos.

Our initial play-off view was too dense because of the connections between teams as well. Teams that played against each other were connected directly. When searching for alternatives to reflect on our choice we discovered a similar visualization in a totally different context**whitehousepath** as explained in the section 4. 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 added an intermediate step between two teams to more clearly indicate how teams competed to become the NBA champion.

We initially also considered a map view to show the teams and their regular competition ranking on a map of the USA. However, this view had no additional value compared to the play-off view except for the geographical position, which has no importance for our visualisation. Furthermore we've found a visualisation of the NBA with a map view **mapviewvisualization** 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 showed in Figure 7. The view consists of 3 coordinated parts:

meaning of last sentence is not clear

Hierarch = sorting = facilitate trends of winners position have a meaning in the play-off view when

- Context section: the top part informs the user of the context of the selected team
- Arrow section: this section illustrates why a statistic has changed 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-offs view. The team's information is also 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 provide context of the current position in the visualization. The team shown in the statistics view is highlighted on this smaller bubble section as well. Replicating this section also alleviates short-term memory issues. It prevents the need to scroll back and forth between the different views constantly.

Arrow section

This section illustrates a change for 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 explained in the play-off view. To give the user a better interpretation of the SRS value of the circle, three other reference circles are drawn. These are transparant with a lightgrey border. They show the maximum, average and minimum SRS value of the NBA 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

add statistics view image here

The value of the change in statistic is shown next to the arrow. The number of players responsible for the change is shown between brackets. Their are shown jerseys next to the arrows as well. These are the jerseys of the two players that had the biggest contribution to the influence represented by that arrow. On the left, there is a possibility to chose a statistic. The possibilities are the PER value, the age, the effective field goal percentage, the offensive rating and the defensive rating. Below this, 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, the league rank, the playoff 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

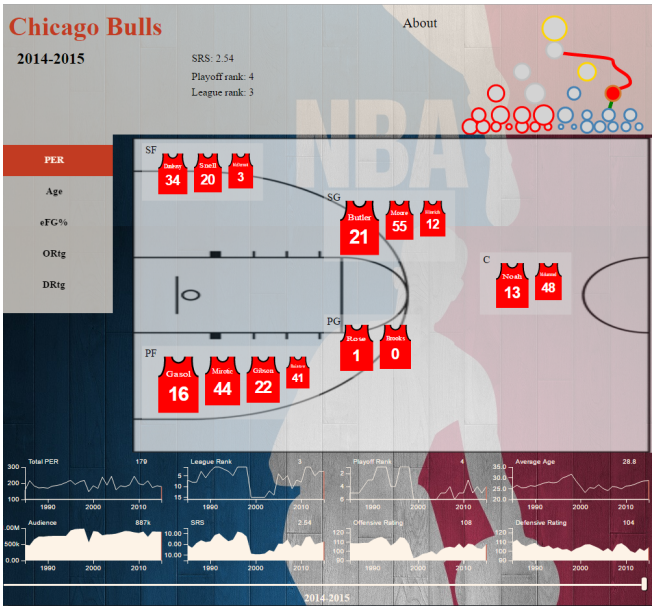

Figure 7. The team view.

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 statistic. By interacting with the visualization, previous seasons can be inspected to try to find explanations or following seasons can be inspected to see if a team responds in a specific way or what the consequences are. 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 was the position of the arrow and jerseys for the players who stayed, which were originally in the team circle, and so the logo was not showed. The design of the arrows did not change. The incoming and outgoing arrows are maybe more intuitevly 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 on the different field positions. The team view is showed in Figure 8. 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 why a statistic has changed compared to the previous season
- Selected statistics section: team statistics and how they evolve over time

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 on its field positions. Players are represented by their jerseys. Jerseys aligned next to each other share the same position, which is indicated as well. The size of a jersey illustrates a players 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 is 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 importnace and because of time and resource constraints, it has not been fully developed.

sketch of small multiples here

Improving the result
Talk about how we improved the data-ink ration in the end..

Technology
To create the visualization, the d3 javascript framework **d3** was used in combination with html5 **html5** and jquery **jquery**. 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 a svg with a specific visualization.

Is this necessary? I don't know what to write here.

sketch of how the page is structured here

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

- A synchrounous call need to be combined with synchronous calls. More specific, when a visitor uses the timeline to scroll through time, the whiping of previous visualizations was not synced with the creation of the visualisation. This resulted in whiping 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, when integrating these views as a whole, would we be able to see the relations and consequences we thought we would see and if we could draw the conclusions we hoped for. 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 transferpolicy in a season, would benefit in one of the following seasons. It was not possible to draw this conclusion and according to us the reason for this is that a whole NBA team contains an average of 15 players. Some players may play a lot more than others and are therefore much more important to the team. This observation is why we could not draw our hoped conclusion, but at the same time we found it so interesting and we wondered if we could find an example to support this observation. The story is about the Chicago Bulls, the team of Michael Jordan who is seen as 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 form those three consecutive wins, Michael Jordan retires and the team is not able anymore to achieve the same. 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 chamionship 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 to become the champion, it seems like a team needs to have a default team with around five core players and one or two star players.

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. Eg. each small multiple of a statisctic in the statistics view on itself gives sufficient information to stand on itselfs. 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 weighed against the duplication of data and use of screen space. Coordinated views alleviate this need significantly as well, 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 3 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 finetune our designs. Although we are satisfied with our result and we are convinced it was the right choice to reach our goal, it had some draw backs. If we would have 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 time developing 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 had to be developed by us.

FUTURE WORK

As with most projects, the result is never 'finished', meaning that there are always extensions and iprovements possible but due to timing or resource constraints they haven't all been implemented. We suggest a number of features that might improve the visualization:

- Smooth transitions between states could improve the user experience. For example when changing year, a transformation of the arrow in the statistics view would help the user see a difference between years. 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. Eg. 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 thus 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 at least can share or save a state of an analysis. One step further is to provide a play-feature. The visitor could them share his exploration and replay it. A simple implemention would ask the visitor for a start date and an end date and would then 'play' the changes of a particular team and characteristic over time.
- We could support users further in looking for patterns by focussing 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.
- 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.

CONCLUSION

We believe the visualization we have created can be of tremendous value for fans 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 four very strong players and the team's performance. It seems 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 has much value.

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Reference should be in alphabetical order and represented by numbers in the text. Style should be set to styleSIG Reference Format, this moment it is set to the style draft

APPENDIX

TERMINOLOGY

NBA

National Basketball Association - The largest, most well-known basketball of the USA.

PER

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

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**srs**.

Playoffs

The National Basketball Association (NBA) playoffs are a best-of-seven elimination tournament among 16 teams in the Eastern Conference and Western Conference (called divisions, pre-1970), ultimately deciding the winner of the NBA Finals**playoffs**.

Jersey

The shirt worn by basketball players.