

Buckets: Basketball Shot Visualization

Peter Beshai



Fig. 1. The main screen, called Player View, showing player details in Buckets. On this screen, users can see brief summary statistics of the selected player (upper left), a shot chart depicting their shooting performance spatially laid out on the court along with filters to control what is visible (mid-left), line charts depicting the player's shooting performance aggregated by distance from the basket (upper mid-right, upper right), aggregated by which side of the court the shots were taken from (lower mid-right, lower right), and a game selecting component to filter which games are included in the data shown in the charts (lower left).

Abstract—Basketball fans are often interested in learning more about their favourite players and most tools today provide long tables of numbers to support these users. However, basketball is a spatial game and can benefit from visualizations to simplify and clarify the communication of a given player's performance. I created Buckets to fill this role. Buckets supports viewing details about individual players, comparing multiple players, and exploring league trends through a variety of interactive charts designed to be used by fans and casual analysts. The focus is on shooting performance and includes three novel chart uses: a filterable shot chart, a simplified distance-from-hoop chart, and a left-right court position partitioned chart. Buckets was shared online as an informal evaluation and was positively received.

1 INTRODUCTION

Sports fans typically enjoy looking at stats for their favourite teams and players, and basketball fans are no exception. Every single shot taken in the National Basketball Association (NBA) is recorded with their SportVU Player Tracking technology and many of the statistics derived from the system are provided freely online via their web site stats.nba.com. While there are numbers representing all the shots taken on the court throughout a given season, much information is lost by discarding the spatial data associated with them. Fans and casual analysts are often stuck sifting through long tables of data to find patterns or statistics of interest.

In 2012, Kirk Goldsberry revolutionized NBA analytics by introducing the shot chart [9], a visual representation of a player's shot performance displayed as a discretized heat map over a drawing of half of a basketball court. Currently, shot charts are being used most frequently as static images produced by experts and disseminated via

news articles. While tools do exist for fans to generate shot charts for any player [4, 24], they have limited to no interactivity and can at times be hard to interpret. Buckets aims to support these fans by providing an interactive, filterable shot chart for every active player in the NBA, while also providing clear legends and descriptions of what is being shown. Beyond shot charts for players, Buckets provides shot charts for each team and each player position, as well as for the league as a whole.

Shot charts work well since they preserve a player's exact x-y position on the court, which is significantly more detailed than a single number in a table. However, we can still gain insight by examining the data in between these two extremes: we can reduce shots into groups based on their distance from the basket, a 1-dimensional measure. Buckets does just this, while also providing a step more towards the full x-y positioning in a shot chart by including charts where shot data is partitioned by which side of the court, left or right, the shot was taken from. These charts provide valuable insight into a player's overall shooting tendencies.

Buckets introduces features for interactively comparing multiple players' visualizations simultaneously, as well as an overview of how the shooting behaviour varies across the league as a whole, across each player position, and across each team.

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2 RELATED WORK

Buckets is designed for NBA fans and casual analysts to discover and share facts about players in the league. In the following sections, related work is explored, broken down by basketball visualizations, general sports visualizations, and visualization sharing techniques.

2.1 Basketball

Visualization of basketball shot data that takes into account spatial location is a fairly recent phenomenon. Goldsberry's CourtVision introduced the shot chart by creating a discretized heat map over an NBA court to represent a player's field goal attempts and their efficiency, which proved effective in demonstrating which players are the best shooters in the NBA [9]. Further work by Shortridge, Goldsberry, and Adams suggested promising smoothing methods and new statistics for rendering shot charts of interest [19]. The shot charts created in Buckets are similar to those described by Shortridge et al. in that they form a square grid over the basketball court and display differences to the league average for a given statistic, but in Buckets more conventional statistics, such as basic field goal %, are used instead of their spatial shooting effectiveness measure. Several other works used scatter plots and heat maps over the court to indicate variation in a statistic of interest [3, 14, 20].

Other visualizations of NBA data disregard the spatial location associated with them. These visualizations have used bar charts [21, 15, 16], histograms [15, 14, 17], scatter plots [8, 16], line charts [7, 6], and node-link graphs [17, 2] to depict their results.

Notably, none of the aforementioned visualizations are available for interactive use by the wide audience of NBA fans. However, given that much of the data used in these visualizations is freely available online, there is an opportunity to reach the masses with appropriate visualizations of NBA data.

NBA.com has an extensive stats section, which focuses primarily on tables of numbers, but also includes basic shot charts depicting each shot a player made in an individual game, as well as a player's efficiency broken down by zones on the court [1].

A recent web site, Nylon Calculus, is dedicated completely to basketball analytics and has a modestly interactive shot chart tool where users can select any player in the league and view their shot chart [4]. However, it is limited to viewing a single player at a time, there is no clear translation between numbers and colours, and users must select the player of interest from a single drop-down menu containing over 400 players. Buckets aims to improve this experience by providing a sophisticated player selector component and by making it clear what the colour encoding in the chart precisely means.

Beyond the basic shot charts, Nylon Calculus is working on a new visualization called TeamSPACE where 5-player lineups are visualized in terms of the areas on the court they use the most [5].

Recently, the Washington Post [12] published novel visualizations depicting the players of the Washington Wizards' shot attempts in a variety of different ways including: a stylized 1-dimensional chart showing imaginary shooting arcs, with a similar feel to SnapShot's radial heat map used in hockey visualizations [18], and dot plots indicating efficiency and frequency by distance from the basket. Buckets offers a number of similar charts to these, with the difference being that they are interactive and users can generate them for any player in the league.

Visualizations not related to shooting in the NBA include Goldsberry's novel interactive visualization of rebounding in the NBA [10] and Luis' visualization of player movement and the plus-minus statistic [13]. A variety of NBA visualizations are available from NBA Savant [24], but the interface can be challenging to navigate, making it inaccessible to a wide audience.

2.2 General Sports

In SnapShot, Pileggi et al. used a similar technique to Goldsberry's shot charts, but for hockey shot data [18]. Instead of breaking the arena into a grid, they created a radial heat map to indicate at which distance most shots were taken from. They also made use of the small

multiple idiom to provide an overview of the data from all the arenas in the National Hockey League (NHL), which was effective in helping analysts discover unexpected behaviour. Buckets draws on their positive experience and uses small multiples to represent teams and individual players for comparison. The radial heat map is a novel method to display the shot data reduced to a single dimension, distance from net, while maintaining the context of the arena. Buckets simplifies the basketball equivalent representation of this data into a simple line chart, but maintains context of where the points correspond to via linked highlighting with a shot chart.

2.3 Sharing Visualizations

When creating visualizations that are designed to be shared broadly across the internet, as is the case with Buckets, previous work has put forth a few best practices. Wattenberg's NameVoyager developed features, explicitly for the "spectator experience," such as smooth animations and large text fields [23]. He speculates these features helped drive interest in the visualization and aided in its spread around the internet. Since his input model was quite simple, all you had to do was type in a few letters of a name, users could share the state they were looking at with simple instructions to generate conversation about the results. Heer, Viegas, and Wattenberg followed up with the Sense.U.S. project [11], which used other helpful features for sharing, including automatic updates to the URL to reflect the current state, a history panel revealing what has been recently viewed, and a comments pane where users could comment on the visualizations right in the application. While Buckets does not implement all of these features, it does have automatic URL updates and smooth animations to better support and encourage sharing.

3 TASKS

Buckets is intended to be used by fans of the NBA, as well as casual analysts. As such, the main tasks that the visualization supports are:

1. Enjoy basketball statistics and visualizations
2. Share basketball visualizations

However, these tasks do not help guide the main functionality of the visualization. For that, Buckets aims to be a tool that can be used to explore and learn more about NBA shooting behaviour, from the level of individual players, by player position, of each team in the NBA, and of the league overall. With this in mind, the following six additional tasks are supported:

3. Discover the shot distributions of players
4. Compare player shot distributions against the league, and against their position
5. Compare player shooting performances against each opponent team
6. Compare player shot distributions against other players
7. Discover the shot distributions of the entire league, of each position, and of each team
8. Compare the shot distributions of teams against each other

To handle these tasks, Buckets uses a variety of visualizations of NBA shot data across three main views, as discussed in the following sections.

4 DATA

Shot data was collected from stats.nba.com for four NBA seasons, from 2011-12 through to the current 2014-15 season. Notably, only two seasons 2012-13, 2013-14 had the full 1230 games worth of data, due to a lockout in 2011-12 reducing the total games to 990, and because the 2014-15 season is ongoing. See Table 1 for a summary of the data counts.

Table 1. Summary of Data Counts

Season	Shots	Players	Teams	Games
2011-12	161,205	478	30	990
2012-13	201,579	469	30	1230
2013-14	204,126	419	30	1230
2014-15	49,742	432	30	307

4.1 Data Acquisition

There was no simple method to collect data on all shots taken during an NBA season from stats.nba.com. However, since it was possible to view shot charts for a given game that depicted all shots taken and whether they were successful or not, I realized there must be a way that I could at least acquire all the shots in a given game. There was. However, there was also no simple way to get a list of all games played in a given season. This left me with the following process to acquire all shots in a given season:

1. Acquire a list of teams and their identifiers (IDs). This only needs to be done once since team IDs do not change between seasons.
2. Use the team IDs to get a list of all games played by a given team. Combine these lists to create a master list of all game IDs for a given season, throwing away duplicates that exist due to two teams being involved in each game.
3. Use the master list of season game IDs to acquire all shots for a given game, for all games in the season.

This process successfully provides all shots taken in a given season, but the visualizations will need some more data in order to enrich the interface with other statistics and player information. Three additional steps were taken to acquire all player information: player details (e.g., name, jersey number, hometown), career stats, and photographs. Importantly, the team associated with a player had to be taken based off of the career stats data, as opposed to simply using the player details data where it was also included because the team can change between seasons and during a season due to trades, which is only reflected in the career stats data from stats.nba.com.

Over the four seasons, three teams changed names: New Jersey Nets became Brooklyn Nets (2012-13), New Orleans Hornets became New Orleans Pelicans (2013-14), and Charlotte Bobcats became the Charlotte Hornets (2014-15). For simplicity, the most recent name is used in the data.

4.2 Data Details

There were four main items of data that are used: Shots, Players, Teams, and Games. These items are stored as tables in a relational database with a variety of attributes. Importantly, the shots table contains positional attributes to enable a spatial rendering of the shots, such as a shot chart, as well as a pre-computed distance-from-basket attribute.

4.3 Data Derivation

The shot data provides the x-y position on the court where the shot was taken from, with precision to approximately the nearest inch. At this fine level of granularity, there are very few overlapping shots with which to produce averages. As such, the shot data is binned into a grid with 1 foot by 1 foot cells, and statistics are computed based on all the relevant shots that are within the cell. Using this grid system, the following statistics are computed for each cell:

- Shot count: the number of shots taken
- Shots made: the number of successful shots
- Field Goal % (FG%): shots made / shot count

Table 2. Position Mapping

Position Used	Positions in Data	Players
Guard	Guard, Guard-Forward	304
Forward	Forward, Forward-Guard, Forward-Center	291
Center	Center, Center-Forward	111

- Shot value: how many points a made shot is worth (2 or 3)

These statistics are computed for multiple subsets of the shot data, all using shots from within a given season. The subsets are:

- League: all shots within the season
- Position: all shots for a given position
- Team: all shots for a given team
- Player: all shots for a given player

Notably, in basketball there are five traditional positions: Point Guard, Shooting Guard, Small Forward, Power Forward, and Center. However, in the data provided by stats.nba.com, seven possible positions exist: Guard, Guard-Forward, Forward-Guard, Forward, Forward-Center, Center-Forward, and Center. Given this discrepancy, I reduced the positions used in the data derivation with the mapping shown in Table 2.

Beyond the four aforementioned statistics computed for each cell, the Weighted Field Goal % (wFG%) is computed using the League and Player subsets as follows (see Figure 2 for description of levels):

```

for each cell (i,j) in the grid
  cellFG% ← FG% of cell (i,j)
  level1FG% ← sum(shots made in each cell in level 1) /
              sum(shot count for each cell in level 1)
  level2FG% ← sum(shots made in each cell in level 2) /
              sum(shot count for each cell in level 2)
wFG%(i,j) ← (cellFG% + level1FG% + 0.5*level2FG%)/2.5
    
```

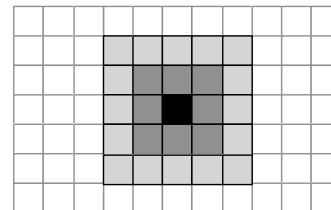


Fig. 2. The levels used in the Weighted Field Goal % (wFG%) computation. Light gray cells are in level 2 with a 0.5 weighting, dark gray cells are in level 1 with a 1.0 weighting, and the black cell is the given cell with a 1.0 weighting. All other cells are not included in the computation.

Distance Data. Beyond the grid shot data, FG% and wFG% statistics were computed using the distance each shot was from the basket, aggregated to the nearest foot. These statistics were computed for the League, Position, and Player subsets as described above. The wFG% has a slightly simpler computation since there are fewer dimensions: $(FG% + (FG% \text{ at } \pm 1ft) + 0.5*(FG% \text{ at } \pm 2ft))/2.5$. The FG%, wFG% and shot frequency statistics were also computed for each player with the data partitioned into shots taken on the left side of the court and on the right side of the court.

Versus Team Data. The average FG% and points per game (PTS) a player scored against a given opponent team were calculated.

Ranks. Rank data was computed for each player in a given season for the following attributes: PTS, minutes per game (MIN), games

played (GP), FG%, shots made or field goals made (FGM), shot count or field goals attempted (FGA), 3-point FG% (3FG%), 3-point FGM (3FGM), 3-point FGA (3FGA).

5 SOLUTION

Buckets is intended to support casual fans of basketball around the world. To make the solution as accessible as possible, I have implemented it using web technologies. To best support sharing, all state that can be changed in the application, for example changing players or filters, is automatically reflected in the URL, as suggested by Heer et al [11]. This allows users to simply copy and paste the URL to share what they are looking at with others. Given the wide variety of possible screens Buckets may be seen on, it has been designed to scale to fit whatever width the browser window is set to, with a minimum required width of 1250px.

To support the 8 tasks listed in Section 3, the solution was split into three separate views:

- **Player View:** For exploring a single player's shooting behavior in detail. This view supports tasks 1 to 5.
- **Compare View:** For comparing the shooting behavior of between 2 and 10 players at once. This view supports tasks 1, 2, and 6.
- **League View:** For exploring the overall league, position, and team statistics in a given season. This view supports tasks 1, 2, 7, and 8.

5.1 Player View

Player View is the initial view that is loaded when a user visits Buckets and can be accessed by clicking Players in the main navigation menu. A full screenshot of the view is shown in Figure 3. The view is comprised of several reusable components: Player Summary, Shot Chart, Distance Charts, Left-Right Charts, Game Selector, Versus Team Charts, Rank Lists, and Player Selector.

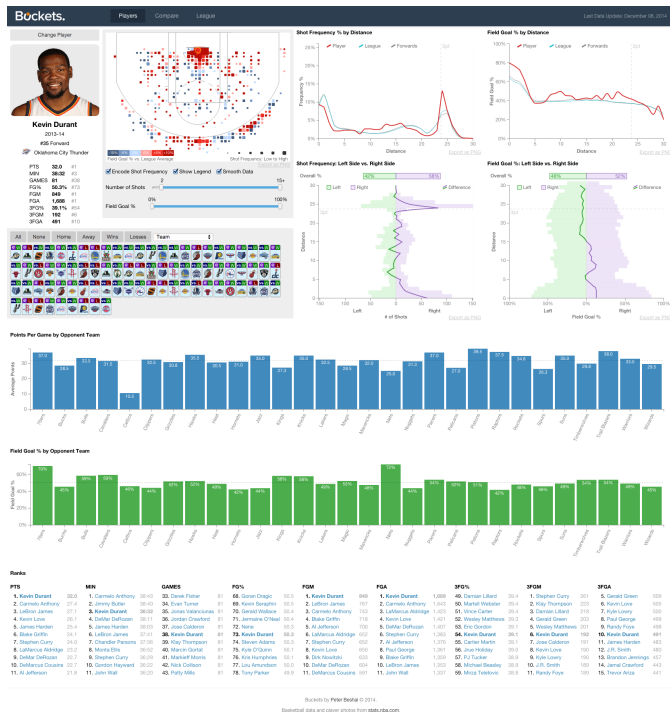


Fig. 3. The full Player View screen. Components are arranged from left-to-right, top-to-bottom as follows: player summary, shot chart and filters, distance charts, left-right charts, game selector, versus team charts, rank lists.

5.1.1 Player Summary

The player summary area, shown in Figure 4, features a photograph of the player, basic information about the player, such as name, position, jersey number, team, as well as a summary of relevant shooting statistics and ranks for PTS, MIN, GP, FG%, FGM, FGA, 3FG%, 3FGM, and 3FGA. It also includes the season from which the data has been taken.



Fig. 4. The player summary area showing Kevin Durant's summary statistics for the 2013-14 season.

The purpose of this component is to provide at a brief summary of the player's most interesting shooting statistics while also giving a visual of which player has been selected, potentially reassuring users of their selection and increasing enjoyment of the system.

5.1.2 Shot Chart

The shot chart, shown in Figure 5, provides a spatial representation of a player's shot behaviour using a combination of colour encoding and size encoding of the derived grid data discussed in Section 4.3. Square shot marks are used in each cell of the grid to represent the shooting data. The square shape was chosen due to the simplicity of implementation and its natural ability to interlock with adjacent squares. Another option, used by Kirk Goldsberry, is to use a hexagon-based grid, which is somewhat more complicated from a computational point of view, but may potentially be more aesthetically pleasing to users. Due to tight time constraints I did not explore this option.

The colours in the shot chart correspond to the player's FG% at that specific location on the court compared to the league average. To increase differentiability between the small marks on the shot chart, only six colours are used: three reds of decreasing lightness representing above average shots, and three blues of decreasing lightness representing below average shots. The darker the colour, the further away the FG% is from the league average. The reasoning behind using red for above average and blue for below average comes from a common shooting metaphor used in basketball: the hot hand. When a player is shooting well, they are said to have a hot hand, or to be "on fire," hence the red encoding. On the other hand, if a player is not shooting well, they are said to be "cold," hence the blue encoding. This colour scheme differs from those found in other common shot charts [9, 4], where red transitions through yellow and sometimes green to blue. The diverging scale I have selected is easier to perceive as it varies primarily in lightness as opposed to hue.

Note that when the "Smooth Data" filter is checked, which it is by default, instead of comparing the player's FG% to the league average FG% in a given grid cell, the player's wFG% is compared to the league average wFG%. This produces a chart with more easily distinguished areas and prevents having adjacent cells with dark red and dark blue.

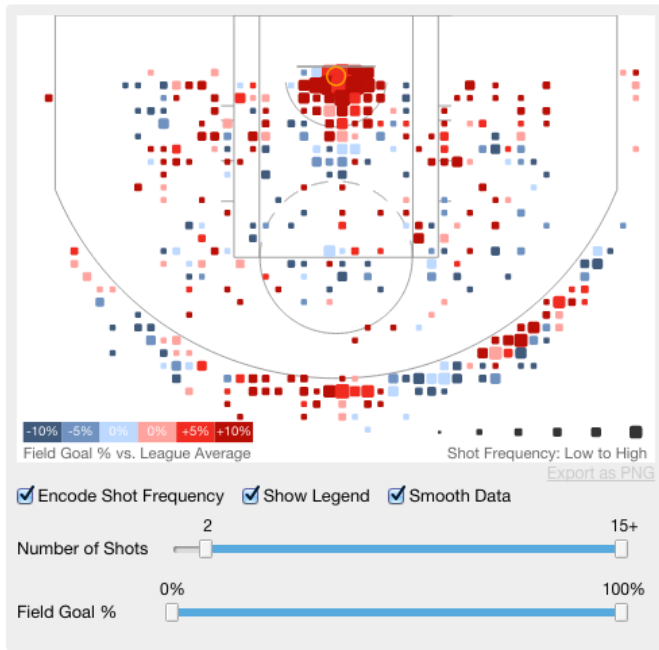


Fig. 5. Shot chart with filters set to their defaults, depicting Kevin Durant's shooting performance from the 2013-14 season.

Given that the likelihood of a shooter's behaviour being substantially different in adjacent one-foot squares is quite low, the smoothed data is likely a more useful representation. See Figure 6 for the same shot chart shown in Figure 5 without smoothing for comparison. I made this filter available for users to toggle to increase the transparency of what is being shown in the shot chart.

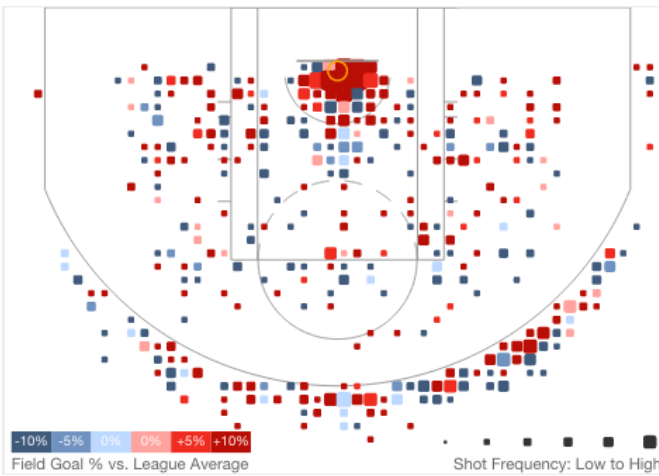


Fig. 6. The same shot chart as in Figure 5 except the "Smooth Data" filter is unchecked, resulting in the shot chart using FG% instead of wFG% to encode the colours of the grid cells.

Shot charts use size encoding to represent how frequently a player shoots from the given location on the court. Size encoding complements the colour encoding well as they can both be separately attended to, and it also matches with how other common shot charts encode frequency to leverage users' previous experiences. In Player View, the size encoding uses a logarithmic scale that maps shots attempted for a given cell from a domain of 1 to 10 to a range of one quarter bin size and the full bin size. If the shots attempted for a cell significantly exceed 10, the rendered mark will exceed the grid bin size producing a desirable overlapping quality, visible in the marks near the basket in

Figure 5. Using a domain of 1 to 10 works well for the number of shots attempted by a single player in a regular NBA season. If a user does not want to use size encoding, it can be toggled via the "Encode Shot Frequency" checkbox control, producing a shot chart similar to Figure 7.

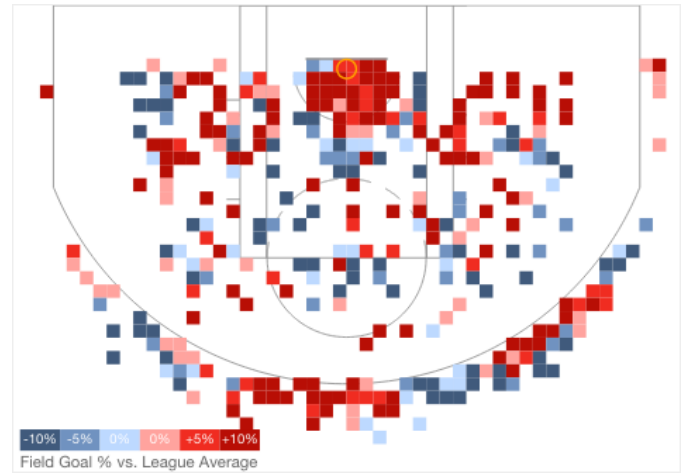


Fig. 7. Shot chart without size encoding.

Two slider filters are provided for users to adjust which shots are included in the shot chart rendering. The first allows filtering based on the number of shots in each bin. The default value is a minimum of 2 for an individual player over a regular season, which sufficiently reduces the noisiness of the chart. The second slider allows filtering based on the FG% in each bin. An example of how these filters affect the shot chart is shown in Figure 8. Note that while adjusting these sliders and while toggling any of the other filters available for shot charts, the marks on the chart will animate smoothly to their new state. This allows users to more easily track the changes, while also potentially increasing their enjoyment of using the system. When any of the filters are modified, the current URL in the web browser is updated to reflect the change in state, making it easy to share exactly what the user is looking at with others.

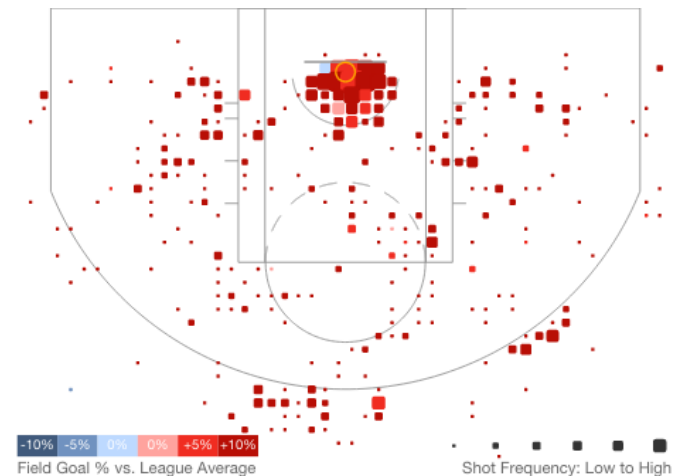


Fig. 8. Shot chart adjusted to show cells with any number of shots, so long as the FG% is greater than 50%.

When a user hovers over a cell in the grid that has data in it, a tooltip appears providing details about what is being shown. These details include the FGM, FGA, either the player's FG% or wFG%, and either the league's FG% or wFG% depending if the Smooth Data filter is checked. When wFG% is being used, the FG% statistic is labelled with a "(3ft)" note, as shown in Figure 9.

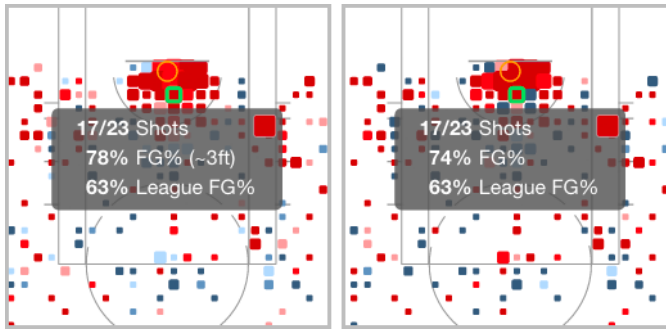


Fig. 9. Shot chart tooltip that becomes visible when hovering over a coloured cell. The left image is the tooltip that is shown when Smooth Data is checked and wFG% is used, while the right image is shown when Smooth Data is not checked and FG% is used.

Shot charts also have an Export as PNG link located just to bottom right of the chart itself. This allows users to easily take the chart that is generated in the browser and share it over a variety of media.

5.1.3 Distance Charts

The distance charts, shown in Figure 10, make use of the shot data aggregated by distance-from-hoop as opposed to the raw x-y position. These charts are essentially the shot charts reduced from two dimensions to a single dimension. Each chart encodes a single attribute: either shot frequency by distance, or wFG% by distance. In this case, FG% is not used directly, since in a given season there is not enough shot data to produce lines that do not zigzag sharply, making it difficult to see trends. By using the wFG% the line is slightly smoothed easier to perceive.

Each chart shows three lines, distinguished by colour coding: the player's average as red, the league average as blue, and the player's position's average as gray. The player's line is twice as thick as the other two to provide emphasis. Similarly, the colour coding of the lines is designed such that the more likely to be interesting lines, player and league averages, stand out more. Beyond the series that are encoded, a dashed reference line indicates the approximate location of the 3-point line at 23.75 feet.

When a user hovers over the chart, an overlay is shown along with a vertical lined crosshair to provide the numeric values at the hovered-on distance. If the user hovers at distances below 25ft, the overlay is shown on the right of the crosshair, otherwise it is shown on the left to prevent it from being clipped. While moving the mouse across a distance chart, linked highlighting is performed on the other distance chart, the two left-right charts, as well as the shot chart, as shown in Figure 11. The left-right charts show a similar overlay as the distance chart does, while the shot chart shows a thick hollow circle, known as the distance indicator, to provide context for what the hovered-on distance means in terms of locations on the court.

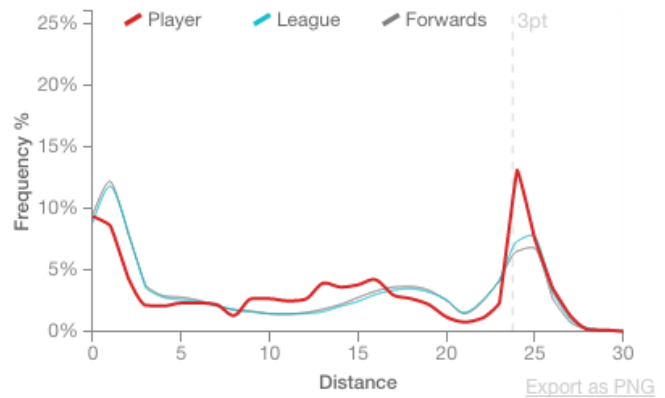
As with the shot chart component, the distance charts also have an Export as PNG control to facilitate sharing.

5.1.4 Left-Right Charts

The left-right charts, shown in Figure 12, depict a player's shooting behaviour partitioned into the left half of the court versus the right half, split down the middle of the rim. There are three main components to the charts: the overall bars, the histograms, and the delta line.

The overall bars ignore distance and simply aggregate the statistics based on whether the shots were taken on the left side, colour encoded as green, or the right side of the court, coloured purple. While these bars provide a summary of the statistic being shown, they can be misleading. For instance, if a shooter takes more 3-point shots from the left side of court, a relatively low percentage shot, and more shots close to the basket from the right side, a relatively high percentage shot, the overall bars will likely show the player as having a higher FG% from

Shot Frequency % by Distance



Field Goal % by Distance

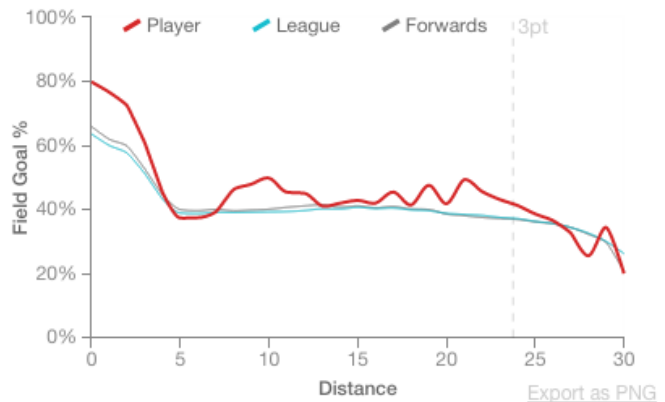


Fig. 10. Distance Charts depicting Shot Frequency % (top) and Weighted Field Goal % (bottom).

the right side. This may suggest to users that the player should shoot more from the right side, which may not be a valid conclusion to draw.

To alleviate this problem, the histograms indicate the statistic's value at a given distance. As with the overall bars, the histograms are colour coded to indicate which side of the court they represent, and they are aligned to the mid-line of the chart and of the overall bars for ease of comparison.

The delta line represents the differences in the statistic between left and right sides at a given distance, and can be used at a glance to determine which side is more favoured by a player. It is coloured green when it is on the left side of the chart and coloured purple when it is on the right side.

When hovering over the left-right charts, or over another chart that has linked highlighting with the left-right charts, such as the distance charts shown in Figure 11, an overlay is shown that indicates the numeric values of the statistics at the hovered-on location and the relevant histogram bars become more saturated. The overlay that is shown has a semi-transparent white background to make it more readable, which unfortunately occludes part of the chart around it. However, the tooltip is carefully positioned to avoid occluding the highlighted histogram bars. If the user hovers at distances below 5ft, the overlay is shown above the relevant data, otherwise it is shown below the data as in Figure 11 to prevent it from being clipped.

Notably the left-right charts have a vertical orientation that makes them markedly different from the juxtaposed distance charts above them. I decided to arrange them in this way to maintain the natural interpretation of left versus right. That is, the data displayed on the left side of the chart represents the left side of the court, and vice versa for the right.

To try and keep the shot frequency chart consistent when switching

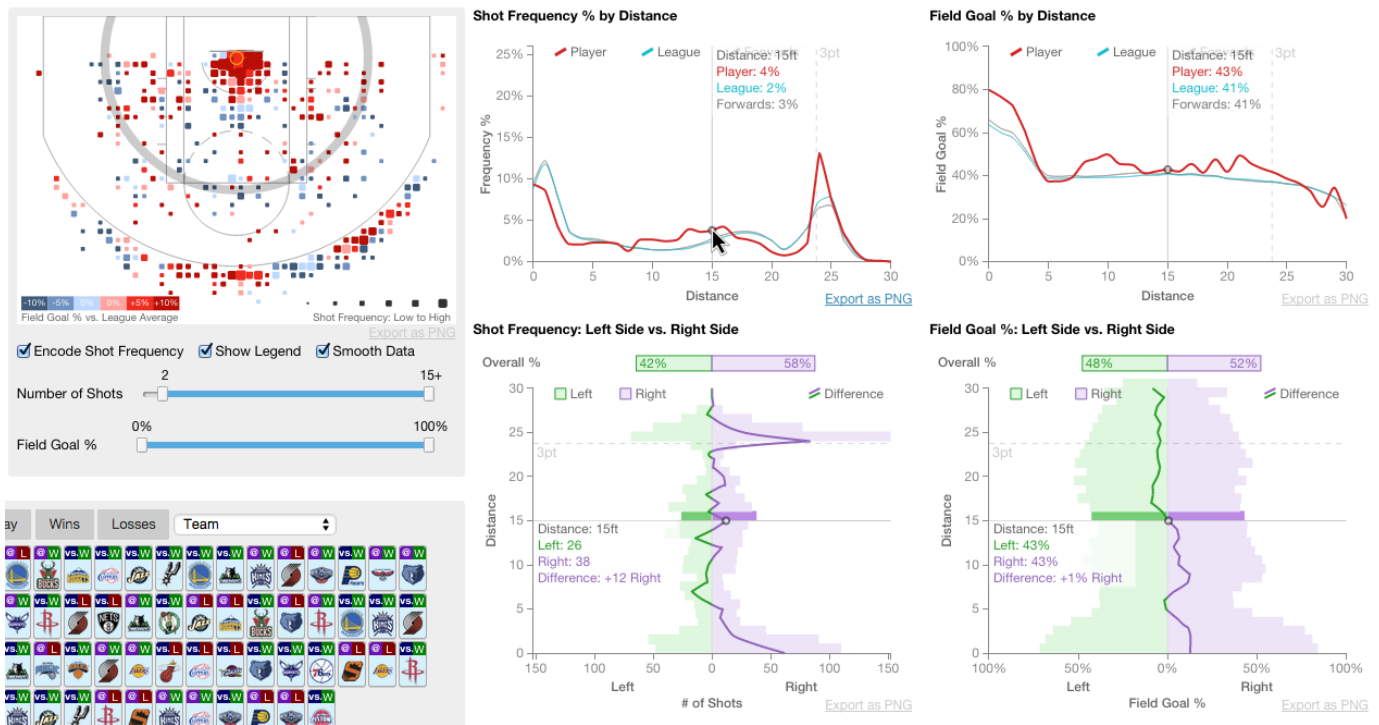


Fig. 11. Linked highlighting on all charts when moving the mouse over either the distance charts or left-right charts.

between players, the axes are set to show between 120 shots left and 120 shots right as a maximum that is extended only in the rare case the player exceeds those values. Setting the bounds higher than 120 to prevent any player exceeding them results in a graph that is poorly scaled for many players.

Similar to the previously mentioned charts, these charts also come with an Export as PNG control to facilitate sharing.

5.1.5 Game Selector

The game selector, shown in Figure 13, is a component that allows users to filter which shots are included when drawing the shot chart, distance charts, and left-right charts based on the selected games. By default, all games are selected. Users can toggle games by clicking on the game glyphs, shown in Figure 14, individually or by clicking and dragging across several of them. There are seven controls to activate predefined sets of games: all games, no games, home games, away games, won games, lost games, and games versus a specified team.

When a user changes the games that are actively selected by any of the aforementioned mechanisms, the charts update to reflect the change in data. Shot charts and left-right charts are redrawn using the different data, with left-right charts having “(Filtered)” appended to their titles. The distance charts are re-drawn with a fourth series added representing the filtered data. This enables users to compare the filtered data line to the player’s usual average, as shown in Figure 15.

5.1.6 Versus Team Charts

The versus team charts, shown in Figure 16, are basic column charts that encode a player’s points per game and field goal % against each team in a given season. Each chart contains up to 30 bars, which can make comparison between any two difficult if they are spaced far apart. To improve this process, a reference line is drawn at the height of a hovered-on bar, as recommended by Talbot et al. [22].

5.1.7 Rank Lists

The rank lists component, shown in Figure 17, shows the ranks and values of the selected player in a variety of statistics, as well as 10 other players who are close in ranking. The statistics for which ranks are computed are: PTS, MIN, GP, FG%, FGM, FGA, 3FG%, 3FGM,

and 3FGA, as discussed in the player summary section. The selected player is indicated by bold-faced font and hovering over player names highlights that player in orange across all of the ranked lists for ease of comparison. Users can switch to a given player’s Player View by clicking their name in the ranks.

5.1.8 Player Selector

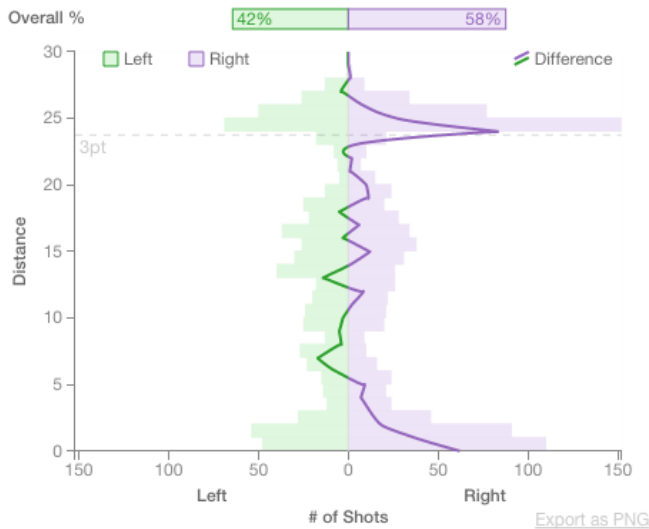
The player selector component, shown in Figure 18, allows users to navigate the space of available players to load into the Player View. The players are first filtered by season, allowing users to see how a given player may have performed differently in one season versus another. Once a season has been selected, users can sort the visible list of players by clicking a button that corresponds to an attribute or statistic. These include: first name, last name, position, team, PTS, MIN, GP, FG%, FGM, FGA, 3FG%, 3FGM, and 3FGA. These sorting mechanisms allow users to quickly explore players that are similar according to the selected metric. When sorted by position or by team, as shown in Figure 19, the players are grouped accordingly with headers indicating the grouping. Users can filter further by typing into a text input box a part of a player’s name, a team name, or a position. Players that match the entered query remain visible, while those that do not match become hidden, as shown in Figure 20. Players are shown with their full name, colour coded by one of their team’s primary colours, and there is a small glyph of the player’s team’s logo to the right of their name. Clicking a player’s name activates that player in the Player View; however, the player names are encoded as links, which enables users to make use of their web browser’s Open in a New Window or Open in a New Tab features should they desire to do so.

5.2 Compare View

Compare View can be accessed by clicking Compare in the main navigation menu. A full screenshot of the view is shown in Figure 21. The view is composed of between 2 and 10 columns, each representing a single player. The default number of columns is 5, the recommended maximum for typical screen displays.

Each column contains the player summary, shot chart, distance charts, and left-right charts described in the Player View section. The charts of the same type are aligned horizontally across the columns to

Shot Frequency: Left Side vs. Right Side



Field Goal %: Left Side vs. Right Side

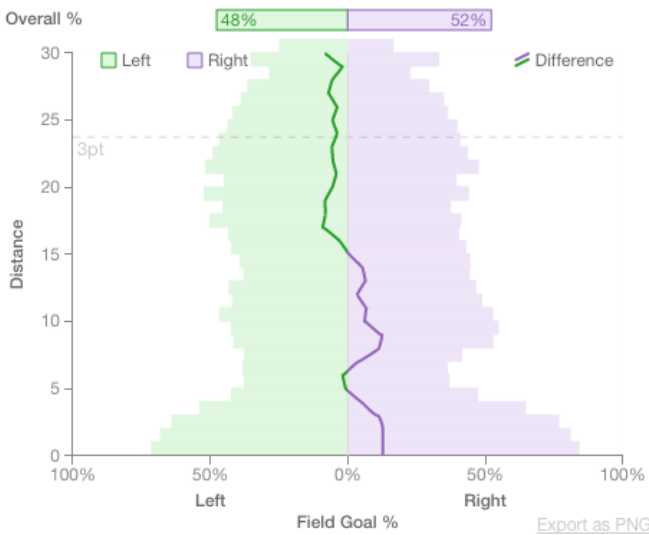


Fig. 12. Left-Right Charts depicting Shot Frequency (top) and Weighted Field Goal % (bottom).

facilitate comparisons. When a user hovers over any of the charts, the linked highlighting described for each of the components in the Player View section occurs for all of the visible charts at once. The shot chart filters described in the Player View are available at the top of the view, as shown in Figure 21, which control the global level of filtering across all visible shot charts.

Users can add new columns by clicking the Add Player button at the top of the view, change the player in an existing column by clicking the Change Player button in each column, or they can remove a column by clicking the X at the top right of each column. Upon clicking the add or change player buttons, the Player Selector, as described in section 5.1.8, is loaded, and the column for which the player is being chosen is highlighted in blue, as shown in Figure 22. Users can select which column they want to set the player in by clicking the Change This Player button when the Player Selector is visible. The set of players assigned to each column is encoded in the URL of the page for ease of sharing.

If vertical scrolling is needed to see all the charts on screen, and the user scrolls past the Player Summary area, the player's name for each column appears at the top of the visible area of the column, as shown in Figure 23. This aids users in keeping track of which player

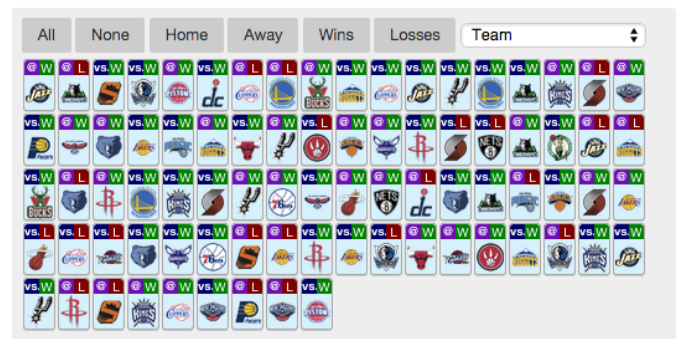


Fig. 13. Game Selector component that shows each game in a given season for a specific player. All games are selected.



Fig. 14. Game glyphs in the Game Selector component. The top left corner indicates whether it was a home game (vs.) or away game (@), the top right corner indicates a win (W) or loss (L), the team logo indicates the opponent, and the opacity and blue colouring indicate if the game is actively included in the chart data or if it has been filtered out.

is mapped to which column.

5.3 League View

League View can be accessed by clicking League in the main navigation menu. A full screenshot of the view is shown in Figure 24. The view consists of charts showing shooting trends for the league, for each of the three positions, guard, forward, and center, and on-demand loading of small multiples for each of the 30 teams in the league. Users can select a season of interest and choose between seeing shot charts representing the average field goal % based on location on the court, and heat maps, shown in Figure 25, which only encode shot frequency by court location. As in Compare View, there is linked highlighting between all the charts in the view, allowing users to compare details across the charts.

The league average shot chart defaults to showing variation in field goal % across the court, but can be toggled to show the points-per-shot metric, which is computed by multiplying the FG% by the value of the shot. This chart, shown in Figure 26, reveals that while shots behind

Field Goal % by Distance

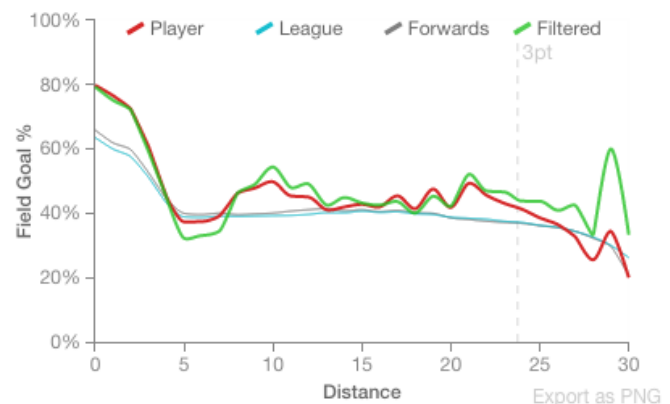
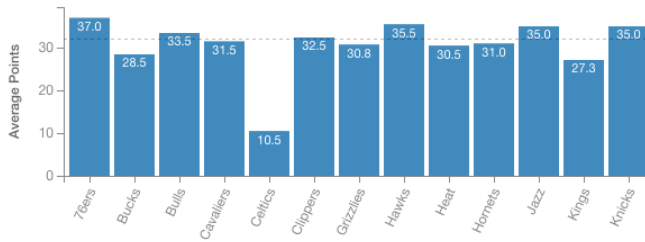


Fig. 15. Distance chart when only won games are selected in the game selector.

Points Per Game by Opponent Team



Field Goal % by Opponent Team

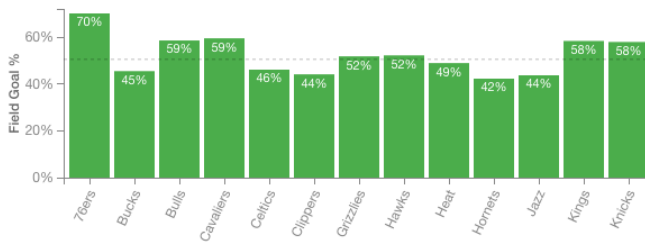


Fig. 16. Versus team charts indicate points per game and field goal % performances against each team in the league.

Ranks

PTS	MIN	GAMES
1. Kevin Durant	32.0	1. Carmelo Anthony 38:43
2. Carmelo Anthony	27.4	2. Jimmy Butler 38:40
3. LeBron James	27.1	3. Kevin Durant 38:32
4. Kevin Love	26.1	4. DeMar DeRozan 38:11
5. James Harden	25.4	5. James Harden 38:03
6. Blake Griffin	24.1	6. LeBron James 37:41
7. Stephen Curry	24.0	7. Chandler Parsons 37:36
8. LaMarcus Aldridge	23.2	8. Monta Ellis 36:52
9. DeMar DeRozan	22.7	9. Stephen Curry 36:29
10. DeMarcus Cousins	22.7	10. Gordon Hayward 36:22
33. Derek Fisher	81	
34. Evan Turner	81	
35. Jonas Valanciunas	81	
36. Jordan Crawford	81	
37. Jose Calderon	81	
38. Kevin Durant	81	
39. Klay Thompson	81	
40. Marcin Gortat	81	
41. Markieff Morris	81	
42. Nick Collison	81	

Fig. 17. Ranks lists for Kevin Durant, with linked highlighting as the user hovers over Stephen Curry's name.

the 3-point line have a low FG%, they are some of the most efficient shots that can be taken.

In this view, the league charts, position charts, and team charts all have their own set of filters. The size encoding parameters have been tuned to work best with a season's worth of data. Recall the shot charts in Player View used a size-encoding domain from 1 to 10. In League View, the league charts use a domain from 1 to 900, the position charts from 1 to 350, and the team charts from 1 to 50.

Similarly, the heat map views are tuned to provide greater detail in areas away from the hoop. Since all teams and positions have the highest proportion of their shots coming from the concentrated area near the hoop, without clamping values the only visible region is the area by the hoop. The league heat map is clamped by default to 1000 shots maximum in a grid cell, position charts are clamped to 250 shots, and team charts are clamped to 40 shots max. All of these clamped values are configurable via the filters built into the view. Adjusting the max values in the heat maps can reveal greater detail in other areas, as shown in Figure 27. Note that heat maps use the common spectrum colour encoding, where value increases from blue to green to yellow to red. This colour scheme was selected due to its recognizability with the general audience expected to be using the application and its ability to separate the data into four distinct layers that are easily perceived.

The 30 small multiples, shown partially in Figure 28, representing the shooting behaviour of each team in the league are not loaded automatically when the view is rendered, as they take a few seconds to initialize. If users are interested in the team data, they can click the

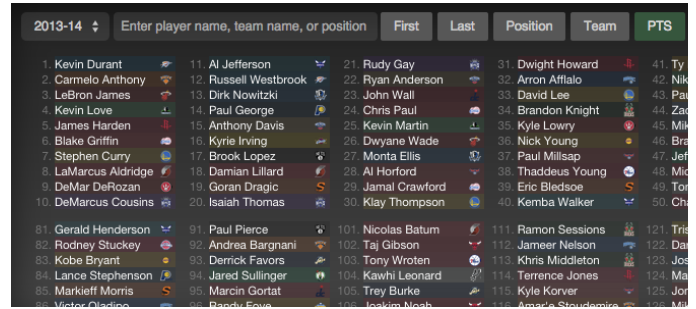


Fig. 18. Player selector sorted by points.



Fig. 19. Player selector sorted by team.

large Load Team Data button to view the charts. Once drawn, users can click the headers of each chart to view a zoomed in version. Each header consists of the team logo, the team name, their overall FG%, FGM, and FGA for the season.

As with the other views, adjusting any filter or loading the team data is encoded into the URL to facilitate sharing.

6 IMPLEMENTATION

To create buckets, I used the following third party libraries:

- **D3.js: Data-driven Documents.** This library was used to draw all the charts besides the continuous heat maps seen in League View. This includes making use of the provided scaling, axis drawing, and general data binding and drawing functions.
- **Heatmap.js.** This library was used to draw the continuous heat maps seen in League View.
- **AngularJS.** This library was used to organize the javascript code. It enabled the creation of reusable components and simplified two way data-binding between controls in the interface and the models that held the data.
- **jQuery Range Slider.** This plugin was used to create the slider controls that allow users to set the minimum and maximum of a range, as seen in the shot chart filters. I styled the sliders myself.
- **PureCSS.** This library was used to provide default styling infrastructure for the web site. In particular, it provided a variety of grid layouts to simplify the web programming.

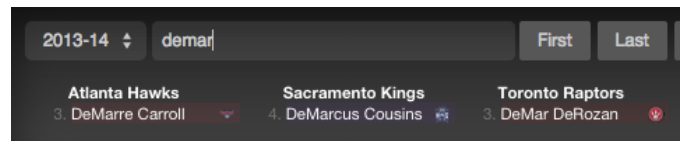


Fig. 20. Player selector sorted by team and filtered by typing.



Fig. 21. The full Compare View screen with five players. The top features a toolbar where users can add players or toggle the visibility of the shot chart filters. The main content consists of one column for each of the selected players, in this case the top 5 scorers in the 2013-14 season.

A friend of mine, Eric Lajoie, created the Scalable Vector Graphics (SVG) image of the basketball court used in the shot charts based on specifications found online.

Besides what is mentioned above, everything else in Buckets was created by myself from scratch. I used the following programming languages and tools:

- **Google Chrome.** The inspector was used to discover the API that stats.nba.com uses to get data for their website.
- **Node.js.** The scripts created to download from the stats.nba.com API were written in javascript and run on the server with Node.js. Node was also used to parse the downloaded data and populate the database.
- **MySQL.** A MySQL database was used to hold all the data.
- **PHP.** PHP was used to create a basic REST (Representational State Transfer) API for Buckets to access data from the database through the web.
- **Javascript.** The Buckets interface is entirely coded in javascript with HTML and CSS.
- **Grunt.** Grunt is used to build Buckets for production, which largely means concatenating and minifying files.

Of note, I had to also create my own colour scale function, since the I could not get the ones in D3 to properly handle a diverging colour scale with bins at -0.05 to 0.00 and 0.00 to 0.05.

7 SCENARIO WALKTHROUGH

In this scenario, Thomas, a Toronto Raptors fan, begins by investigating the shooting behaviour of veteran role players on the Toronto Raptors. He then explores the development of his favourite player Kyle Lowry, and ends by examining the variations in team shooting behaviour.

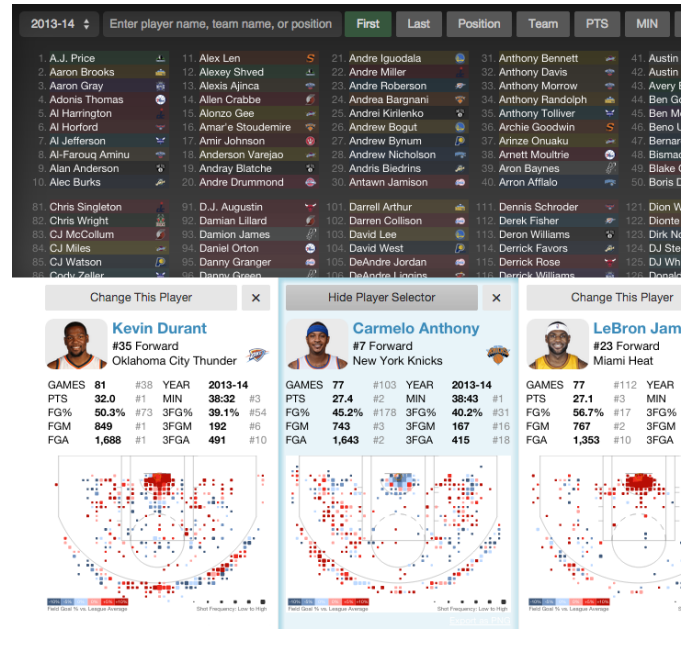


Fig. 22. Compare View with the player selector open. Carmelo Anthony is selected as the player to be changed.

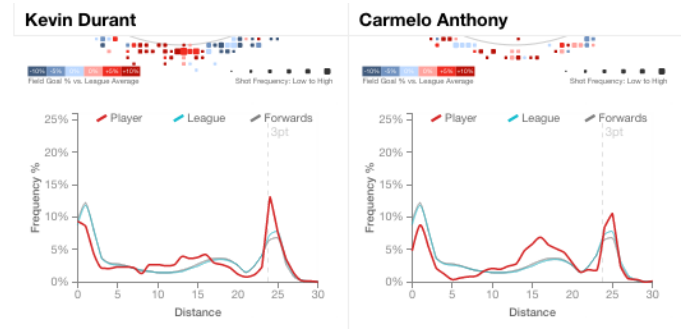


Fig. 23. When scrolling in Compare View, player names appear at the top of the visible area of the columns.

Upon loading Buckets, Thomas is presented with the Player View screen showing Kevin Durant's stats from the 2013-14 season. He clicks the Change Player button and types "raptors" into the text field to filter the results, shown in Figure 29. He clicks Steve Novak, a player known to be exclusively a three-point shooter. Novak's player details load and Thomas is somewhat surprised to see just how true Novak's statistics are to his reputation. While he only shot 146 times, 122 of them were three pointers, and his habits are clear in the distance charts, shown in Figure 30.

Impressed by Novak's discipline to stick to his role as a three-point shooter, Thomas explores another veteran role player on the Raptors, Chuck Hayes. Hayes' role was primarily to defend larger players and to limit his offense to high percentage shots, like those in the paint. His shot chart confirms that he took very few shots over the course of the season, all coming within 11 feet of the basket, shown in Figure 31.

Thomas holds a negative outlook towards another player on the Raptors from the 2013-14 season, John Salmons, recalling many times the player missed critical shots from relatively close proximity to the basket, so he loads up Salmons' player view to gather some insight. The distance chart, shown in Figure 32 reveals the reality was far worse than expected; Salmons shot a lowly 36.3% from the field, averaging between 7% and 22% worse than the league average from within 12 feet of the basket. Surprised by how low the numbers are, Thomas

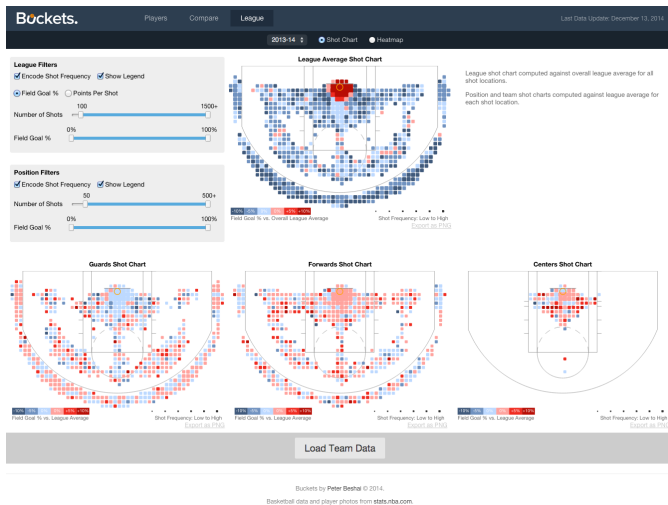


Fig. 24. The full League View screen without team data. The top chart and filters are for the overall league average, followed by three charts representing the positions in the league. Team data can be loaded on demand, not shown here.

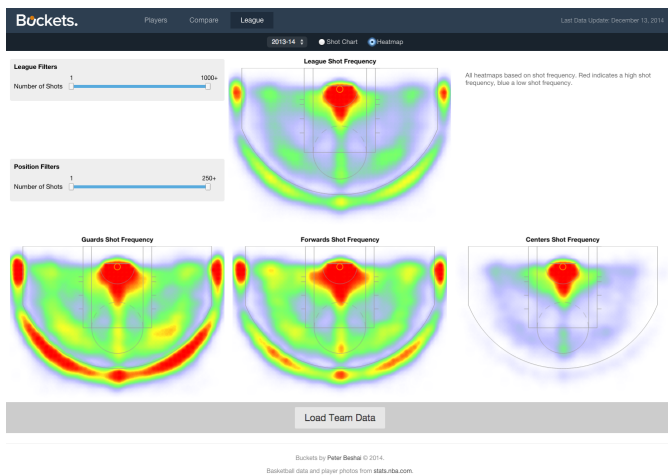


Fig. 25. League View showing heat maps.

exports the PNG of the distance chart and shares it with his friends online. Thomas filters the active games by wins and then by losses to see how Salmons' performance may have affected the team overall. He discovers that in wins, Salmons shot an outstanding average of 47% from just outside the three-point line, but in losses, he shot 14% worse, at 33%, shown in Figure 33.

Thomas then loads up his favourite player, Kyle Lowry in Player View and discovers that he is actually one of the most prolific three-point shooters in the league, ranked #7 in 3FGA and #9 in 3FGM. He recalls the in-game announcers often mentioning how Lowry loves shooting from the left side of the court, and he confirms that he does favour the left side of the court overall and that around 64% of his shots by the three-point line are on the left side of the court, shown in Figure 34. Curious to learn more about his favourite player, Thomas switches to the Compare View to see how Lowry has changed over the last few seasons.

Thomas removes one of the columns and sets the remaining four to be Kyle Lowry from 2011-12 through to 2014-15. He discovers that in terms of his shot distribution by distance, his play style has not changed much over the past four seasons, but his shooting efficiency has improved each year, with the 2014-15 season being the best so far,

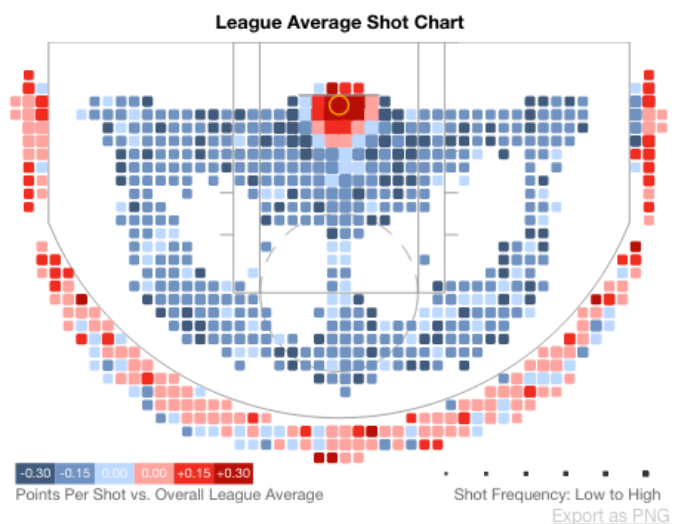


Fig. 26. League average points per shot chart in 2013-14.

as shown in Figure 35. Thomas notices that in 2011-12 Lowry shot more from the right side of the court, then when he was traded to the Raptors in 2012-13 he was even on each side. In 2013-14 and 2014-15, perhaps due to establishing a system and consistency with the team, he had similar shooting behaviour, favouring the left approximately 10% more than the right, as shown in Figure 36.

Thomas moves to the League View and loads the team data to compare how the Toronto Raptors shoot with the two teams that made the NBA Finals, the San Antonio Spurs and the Miami Heat. He learns that Miami and San Antonio had the two highest team field goal percentages in the NBA at 50.9% and 49.0% respectively, while the Raptors are fairly average at 45.3%, as shown in Figure 37. It is difficult to see many differences at a glance in the shot charts between these three teams who are all above average in the paint and variable by the three-point line, so Thomas switches to the heat map view. He notices that Miami's red and green regions are smaller than other teams, as shown in Figure 38, and speculates that it may be due to increased precision in where they take shots from as a team, but it remains unclear to him if that is the case or not.

8 DEPLOYMENT

In an effort to evaluate how well Buckets supported tasks 1 and 2, enjoying and sharing basketball visualizations, I hosted Buckets online at <http://peterbeshai.com/buckets> and shared the link on Twitter. I wrote the following tweet on December 5th, 2014 at 10:07 PST:

Just released my #NBA Shot #Visualization: Buckets!
<http://peterbeshai.com/buckets>. Would love to hear feedback @kirkgoldsberry @NylonCalculus

Several authors at the Nylon Calculus checked out the site and began tweeting about it. By the end of the day, I had heard positive feedback from Kirk Goldsberry, there was 31 retweets, 31 favourites, over 15000 views of the tweet, and many others sent out other tweets about Buckets.

Over 20 people tweeted praise about the site, saying things such as:

so peterbeshai.com/buckets by @pbesh is the coolest and if playing with it doesn't bring you joy I can't help you.

Incredible resource for viewing/comparing NBA player scoring stats peterbeshai.com/buckets/app/#/...

Holy schnikes, Batman. This changes the whole ballgame. peterbeshai.com/buckets/app/#/...

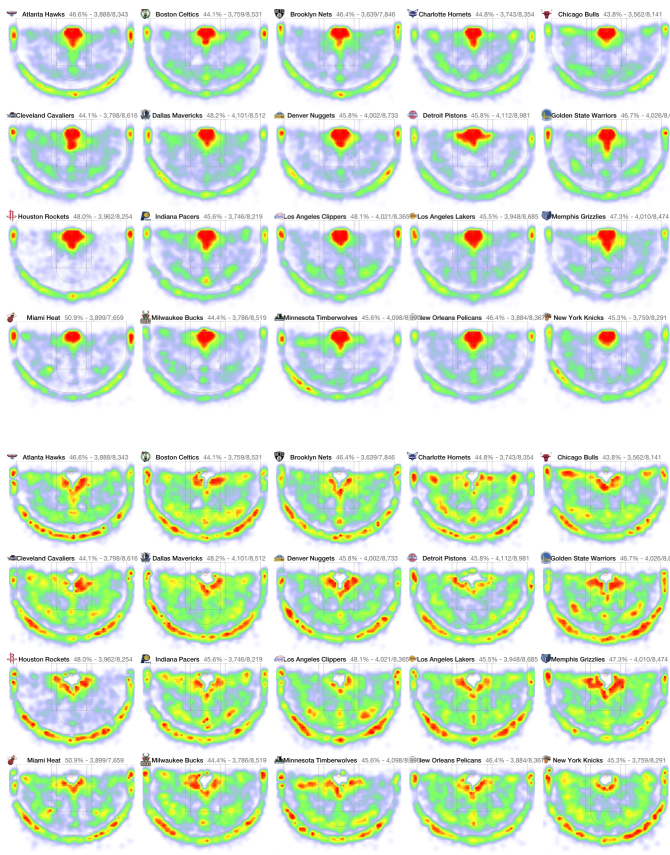


Fig. 27. Team heat maps with default settings (top) and with reduced maxes (bottom).

Fun, intuitive app for basketball shot analysis.

A post was made about Buckets on Flowing Data, a popular Info Vis blog, sharing a summary of the things you can do with Buckets in a positive light. As of December 13, 2014, @FlowingData's tweet about the post has received 29 retweets and 41 favourites on Twitter.

Some non-basketball fans commented positively on Buckets, saying things such as:

If I was more into basketball, I would be obsessed with this site: peterbeshai.com/buckets/app/#/...

Others began sharing insights they discovered while using Buckets:

Look at Anthony Davis' shots in wins vs losses. Higher in the paint when winning - feed him the ball! peterbeshai.com/buckets/app/#/...

beautiful nba stat visualizations by @pbesh - this is what it looks like to be a good shooter in basketball peterbeshai.com/buckets/app/#/...

Pretty nifty site by @pbesh. Here is #Wizards Wall's FG%, but keep telling me he should shoot as often as he does.

Check out the growth of James Harden from 2011 to now. Great stuff from @pbesh! peterbeshai.com/buckets/app/#/... #Rockets

Want to stop Westbrook at the rim? Force him left. He is shooting 64% from the right side and 50% from the left peterbeshai.com/buckets/app/#/...

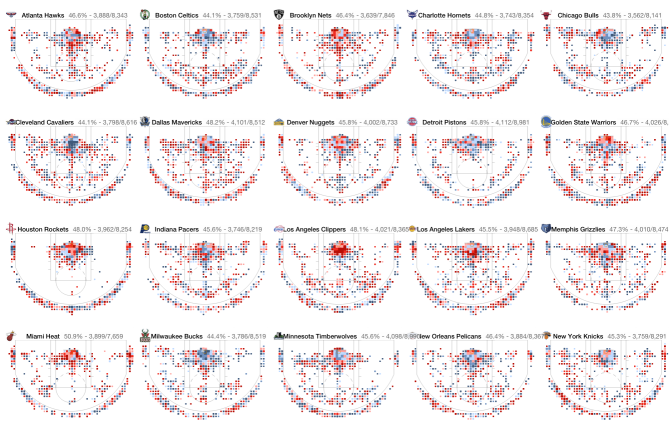


Fig. 28. Team small multiples in League View.

A sports news site, Hoops 76, wrote a brief article listing five insights they discovered about players for the Philadelphia 76ers from using Buckets.

Two people provided suggestions and criticisms:

@pbesh About the only thing I'd suggest is make perhaps the "boxes" a little bigger as it makes it slightly harder to make comparisons. Like if I want to see how tow guys shoot at the right elbow, there are about 20 different plot points.

@pbesh awesome! Would be amazing if you could filter the vs team stats to either just this season or last X seasons. Great job though!

One person played a small game with Buckets online by tweeting the following with an attached image of a shot chart:

Let's play a game- name this player by their 13-14 shot chart @HPbasketball @bballbreakdown @pbesh @AustinClemens2

I also shared Buckets on Reddit, Facebook, and over email, which resulted in similar types of responses as seen on Twitter.

9 DISCUSSION AND FUTURE WORK

Given the results of the Twitter deployment, it appears that Buckets adequately supports tasks 1 and 2, the enjoyment and sharing of basketball visualizations. Many users had positive remarks about the site, and those that shared used both the URL updating functionality and the export as PNG feature. The remaining six tasks are supported as described in the Solution section, and backed up by the various comments users made about the system. For instance, the comment on John Wall's shooting behaviour shows support for tasks 3 and 4, the suggestion to extend the "vs team stats" to support multiple seasons at once showed interest and partial support for task 5, a Reddit comment about comparing top point guards in the league showed support for task 6, and various comments about the Houston Rockets not shooting midrange shots showed support for tasks 7 and 8.

My decision to use a semi-pixel-dense layout as opposed to the more standard spacious layouts found on the web seems to have worked well. Users discussed Buckets as being a "data dashboard" and it gave the impression that there was a lot to explore and learn about by using the system. The layout allowed the shot chart, distance charts, left-right charts, player summary and the game selector to all be visible at the same time on the Player View page, which maximized the visibility of linked highlighting between the charts and provided a big impact to users on their first arrival.

The distance indicator on the shot chart worked well with the distance charts, as the benefit of the distance charts is that they are easy

to interpret at a glance, but suffer from being removed from the context of the basketball court. With the distance indicator, it is easy to understand just where the shots at a specified distance come from.

The shot chart itself is aesthetically pleasing, which is good for task 1, but it can be difficult to interpret. With so many small bins representing shots it is at times challenging to see patterns. I mitigated the issue by smoothing the data using an approximate 3ft radius, but as one user pointed out, it may be helpful to have a coarser granularity available as an option. With such small bins, it is challenging to do a zone-based analysis. For instance, it is hard to say if Chris Paul is a better shooter from the left wing than Kyrie Irving, as there are 20 bins in the left wing that would need to be manually compared. One solution to this problem could be to draw the bins as they are, but colour them based on predefined zones on the court. This seems to be the method used commonly in Kirk Goldsberry's infographics for Grantland. Another option is to allow users to draw a selection on the chart, which is then aggregated and coloured according to the overall contents. This method grants the user more control, but requires input to be seen, which may not be desirable if the areas of interest are often in the same standard locations or zones.

The shot chart filters work well for reducing the noise in the chart by limiting the minimum number of shots in each bin, and for looking at subsets of the data based on field goal %. One issue here is that the bins are coloured based on FG% vs the league average, not based on the absolute FG%. As such, adjusting the filter for FG% cannot handle the task of showing only the red bins, or only the blue bins. Another filter, FG% vs league average, needs to be added for that to work. Furthermore, once a user has changed these filters, they are persisted in the URL for ease of sharing, but this has another side-effect: it is difficult to reset the filters to their default values. Refreshing the page causes it to load exactly as you are seeing it and there is no "reset to defaults" button. A user needs to either remember what the defaults are and set them manually, or to remove the relevant parameters from the URL's query string.

The distance charts are great for providing a quick summary of a player's shooting behaviour, but they do not easily support looking at aggregate statistics for regions of larger than 1ft in width. It would be good if the user could click and drag to select a range they were interested in and be able to see summary statistics for how the shooter performed within the region. For example, this would enable a simpler comparison of 3-point shooting ability, since it essentially maps to any shots beyond 23.75ft.

A weakness of the distance charts and left-right charts is that there is no encoding of frequency in the charts that depict field goal %. As such, there are times when a player appears to be extremely accurate from a specific location on the court, but it is solely due to a very small sample size, which can be misleading for users. A potential solution to explore as future work would be to encode frequency into the field goal % charts, perhaps by varying the thickness of the lines, or bars in the histograms, to indicate frequency. It may also be worth exploring the use of a single line that encodes FG% over distance along with frequency based on thickness to create a "signature graphic" for any given player that summarizes their shooting behaviour in a stylized manner.

The game selector component works well for filtering the data in the charts, but it can be improved in two ways: 1) when games are filtered, the player summary stats should update to reflect the reduced data set, and 2) there should be a blink comparator button. Currently a user can manage doing blink comparisons between the charts by quickly mousing back and forth between two buttons (e.g. wins and losses, or home and away), but it is somewhat more difficult than simply clicking the same button to toggle between two states.

The player selector component enables users to filter and sort players in a variety of ways, however it produces a confusing layout when filtering based on what a user has typed, as seen in Figure 29. A limitation of the component is that it only supports sorting on one attribute, which unfortunately does not allow users to do commonly interesting sorts, such as by position then by points per game, or by team then by field goal %.

The versus team charts provide a very basic summary of a player's shooting performance against each opponent team in the league, but when a user discovers an anomaly, there is no way to investigate further. A drill-down feature that provided game details when clicking on a bar would be a helpful addition.

While compare view provides basic functionality to see multiple players' charts aligned and linked together, it could be further improved by including a large single chart above the columns that aggregated all the active players' data. For instance, this chart could be a shot chart where each player had a unique hue and frequency or FG% was indicated by lightness variation to provide a visualization of the geometry of the group of players, which may be useful for understanding line-ups. Similarly, the chart could be toggled to any of the distance line charts that included series for each of the players.

Besides the large single chart, compare view could be augmented by including the ranks component seen in player view, but restricting its contents to the set of active players being compared.

Another feature left as future work is Match-up View, a feature that allows users to select two teams and view an analysis of how they perform against one another.

To best support task 2, all views in Buckets could support data export as CSV. This would allow analysts to take the data they discover in Buckets and continue analyzing it using their tools of choice.

Lastly, several users mentioned a video demonstrating the features of Buckets, or a built-in tour explaining what everything is would be very welcome. This may be an important part of creating successful semi-complex data dashboards for casual users, and should be investigated further.

10 CONCLUSION

I created Buckets, a tool for visualizing basketball shot data from the NBA aimed primarily at supporting casual users in enjoying and sharing basketball statistics and visualizations. It comes with three primary views: Player View for exploring shooting performance details of a single player, Compare View for comparing the shooting behaviour of multiple players against one another, and League View for discovering how the league performs overall. Novel features include a filterable, interactive shot chart, line charts representing shooting performance against distance from the basket, and charts that partition shots into the left and right side of the court to analyze player preferences and tendencies. The visualizations were shared online to evaluate how casual fans and analysts felt about the system. The responses were strongly positive and provided evidence that Buckets effectively supports a variety of tasks based around discovering, comparing, and sharing basketball shooting data.

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11 APPENDIX

This appendix consists entirely of the screenshots referenced in the Scenario Walkthrough section of the paper.

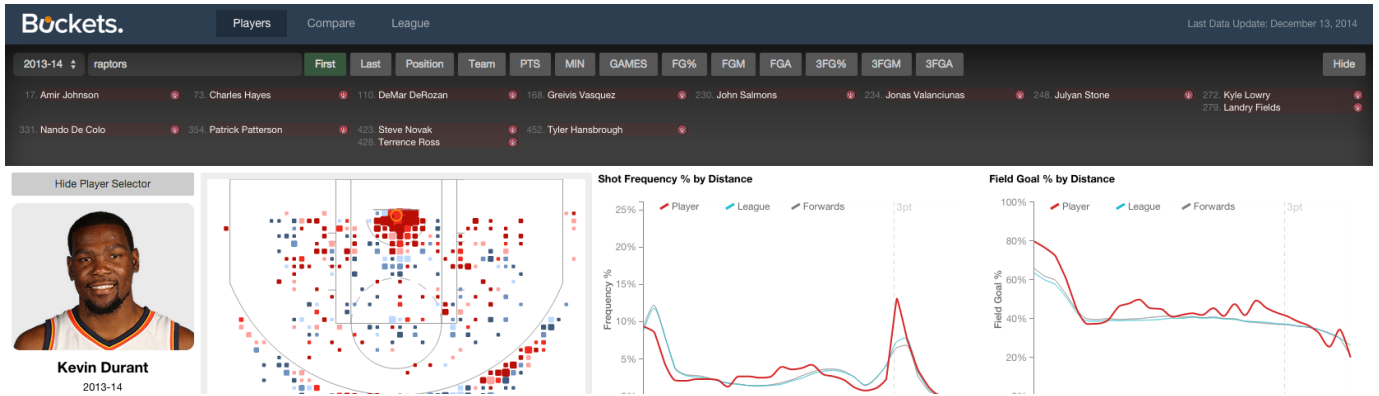


Fig. 29. Scenario: Players are filtered by those on Toronto Raptors

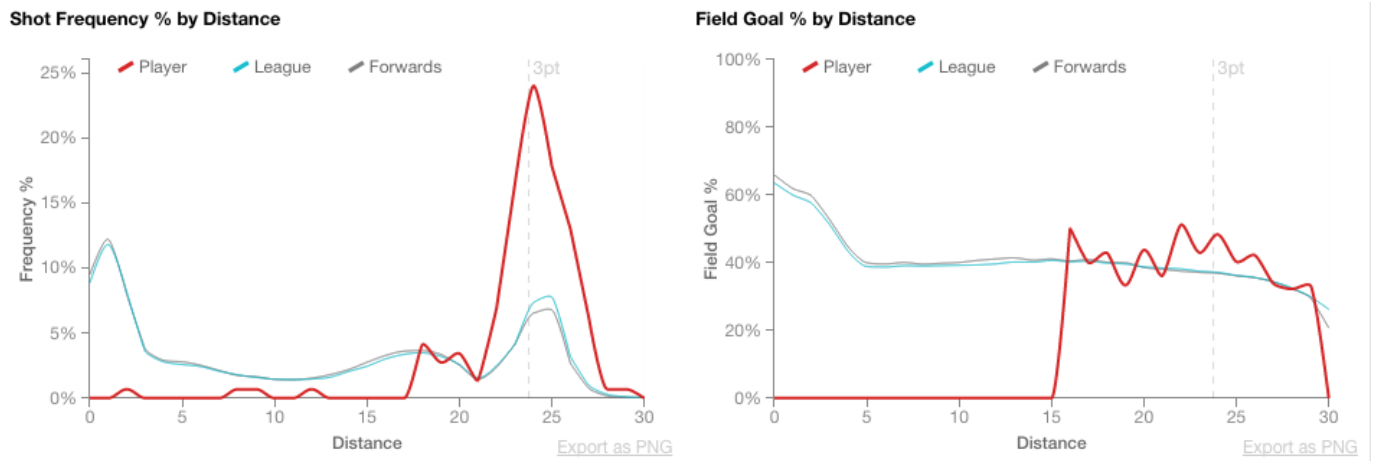


Fig. 30. Scenario: Steve Novak's 2013-14 distance charts confirm his role as a three-point specialist.

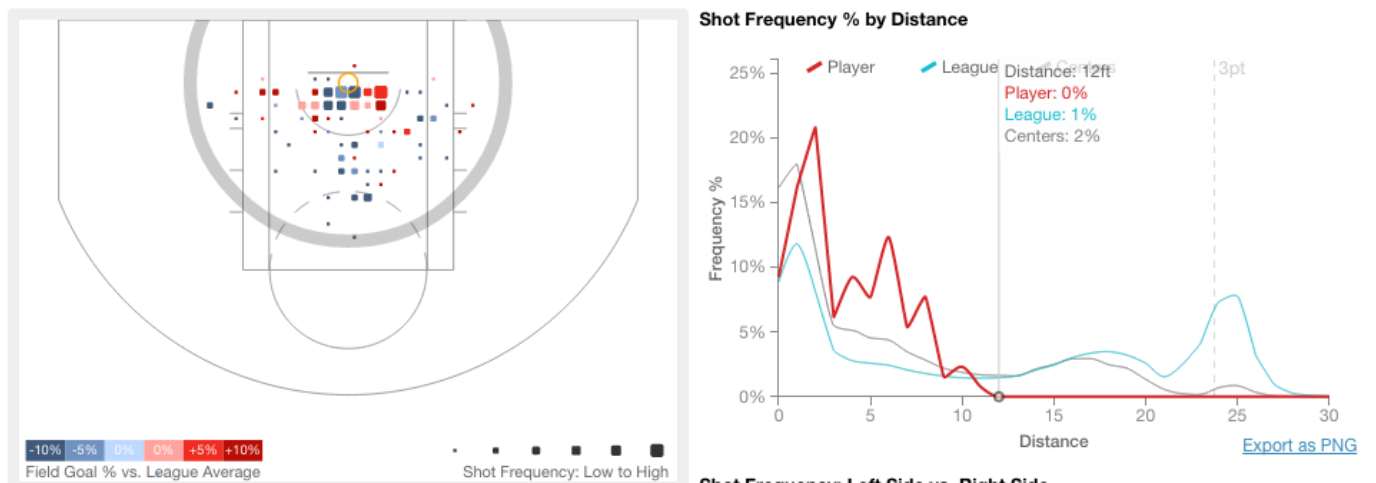


Fig. 31. Scenario: Chuck Hayes restricts himself to shooting close to the basket.

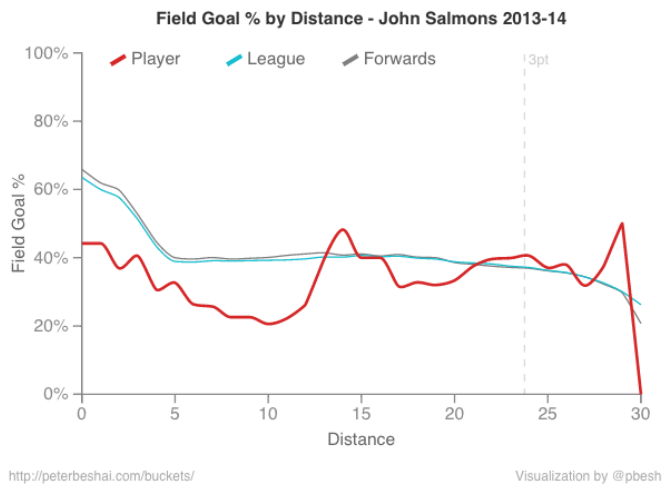


Fig. 32. Scenario: The exported PNG of John Salmons' 2013-14 FG% by distance chart.

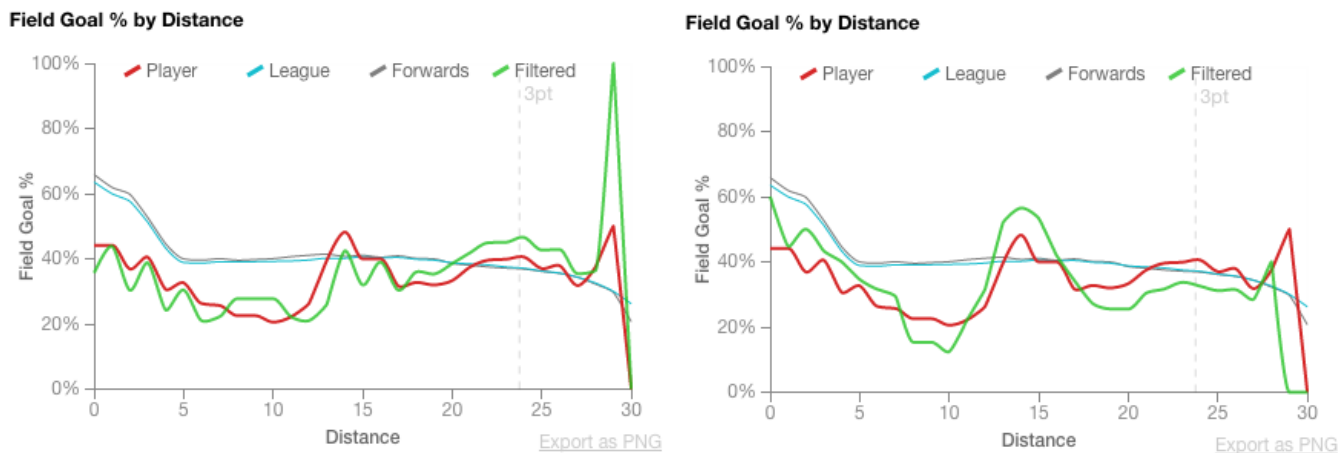


Fig. 33. Scenario: John Salmons' FG% by distance charts filtered by games won (top) and games lost (bottom).



Fig. 34. Scenario: Kyle Lowry in 2013-14 favours the left side of the court when shooting three-pointers and midrange shots.

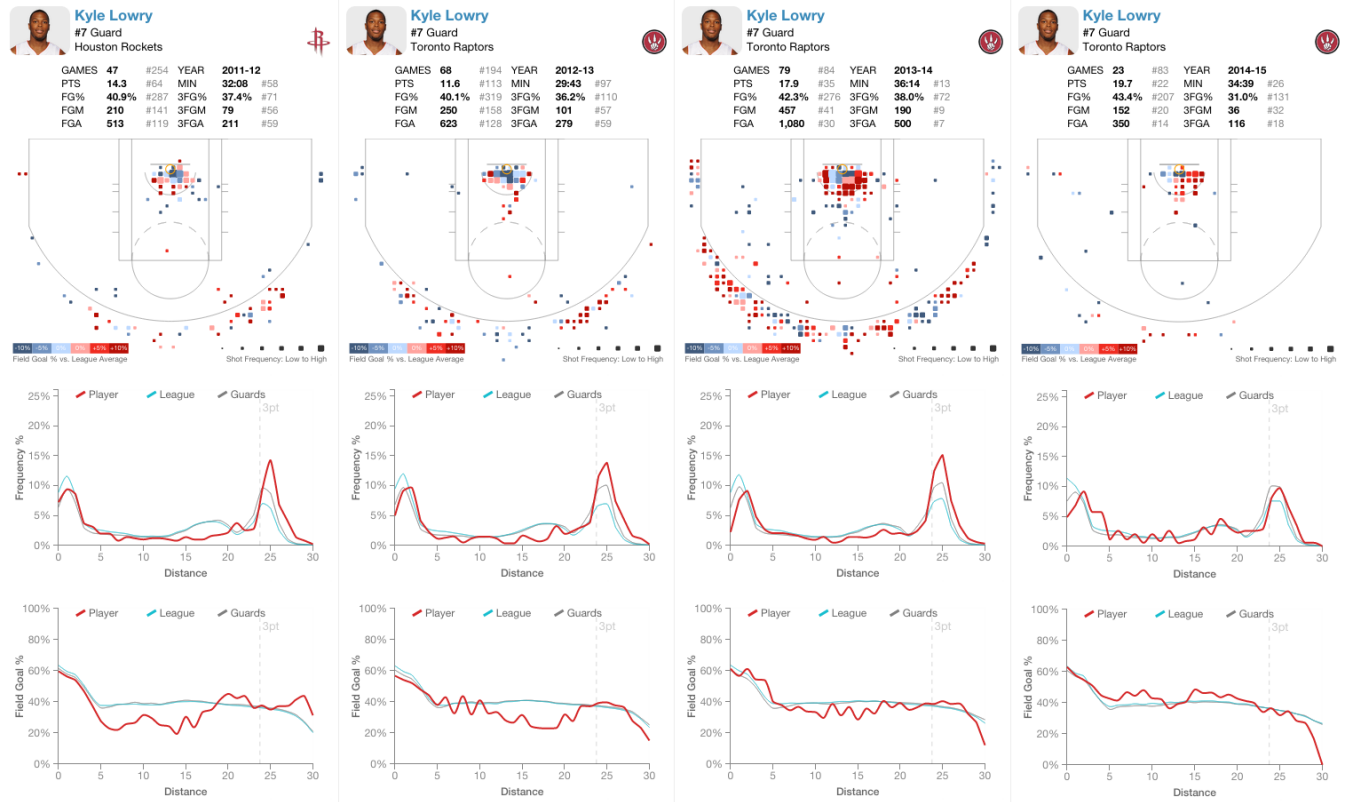


Fig. 35. Scenario: Kyle Lowry's shooting from 2011-12 through the 2014-15 season.

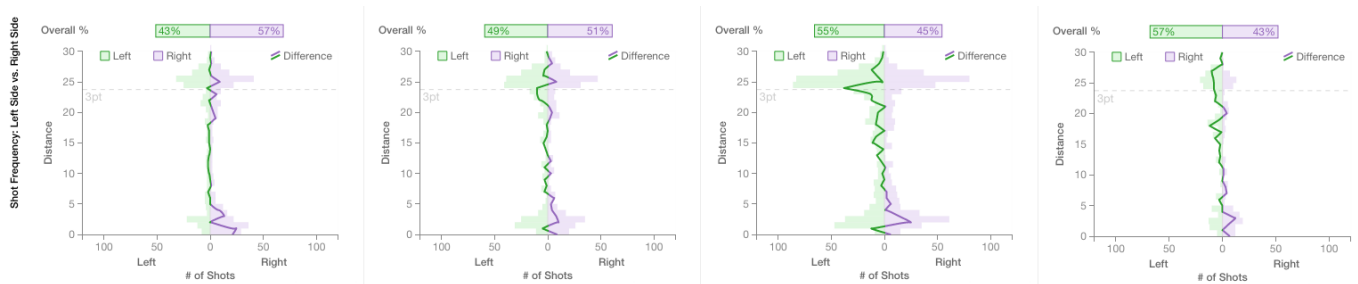


Fig. 36. Scenario: Kyle Lowry's shooting side preferences from 2011-12 through 2014-15.

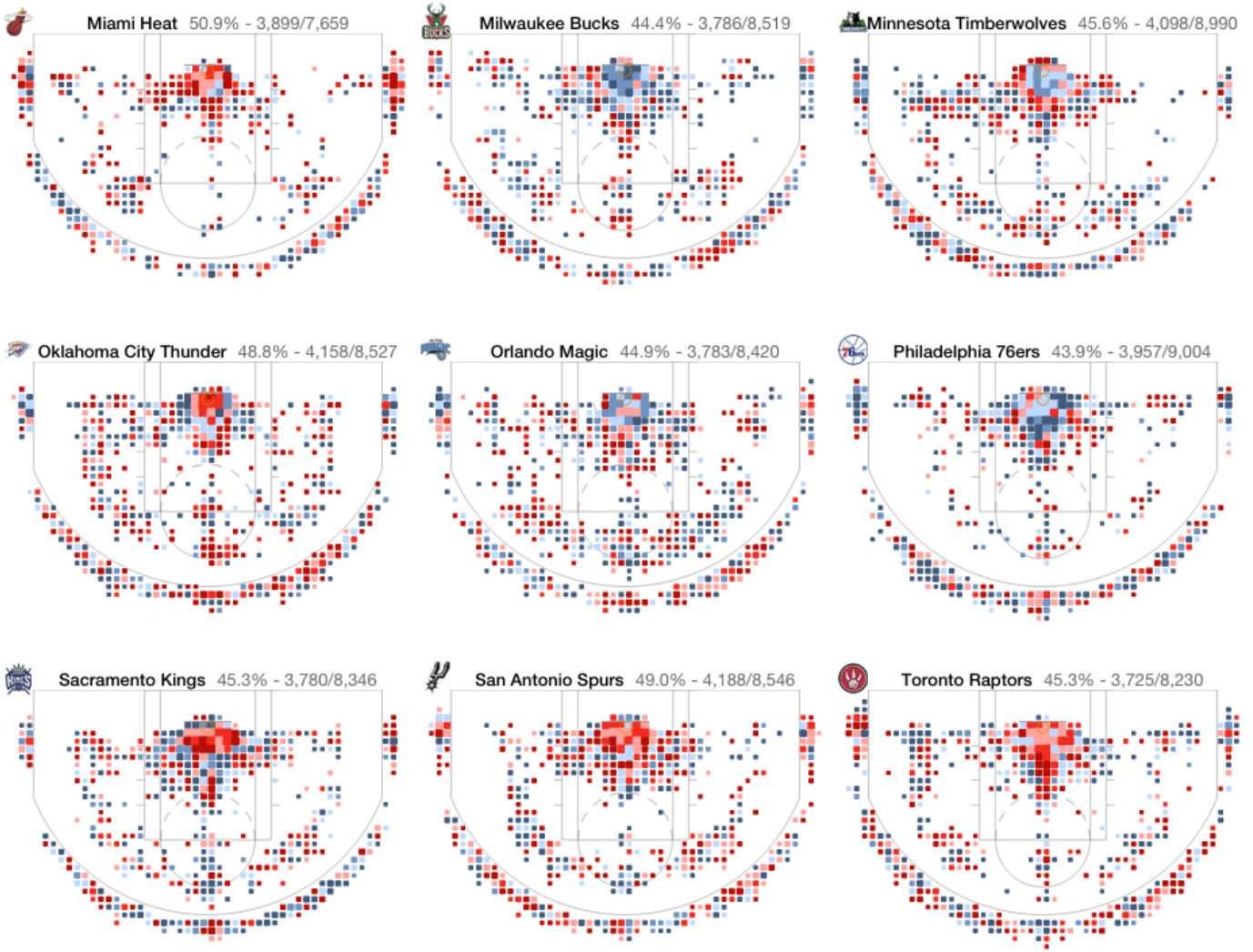


Fig. 37. Scenario: Miami, San Antonio, Toronto shot charts.

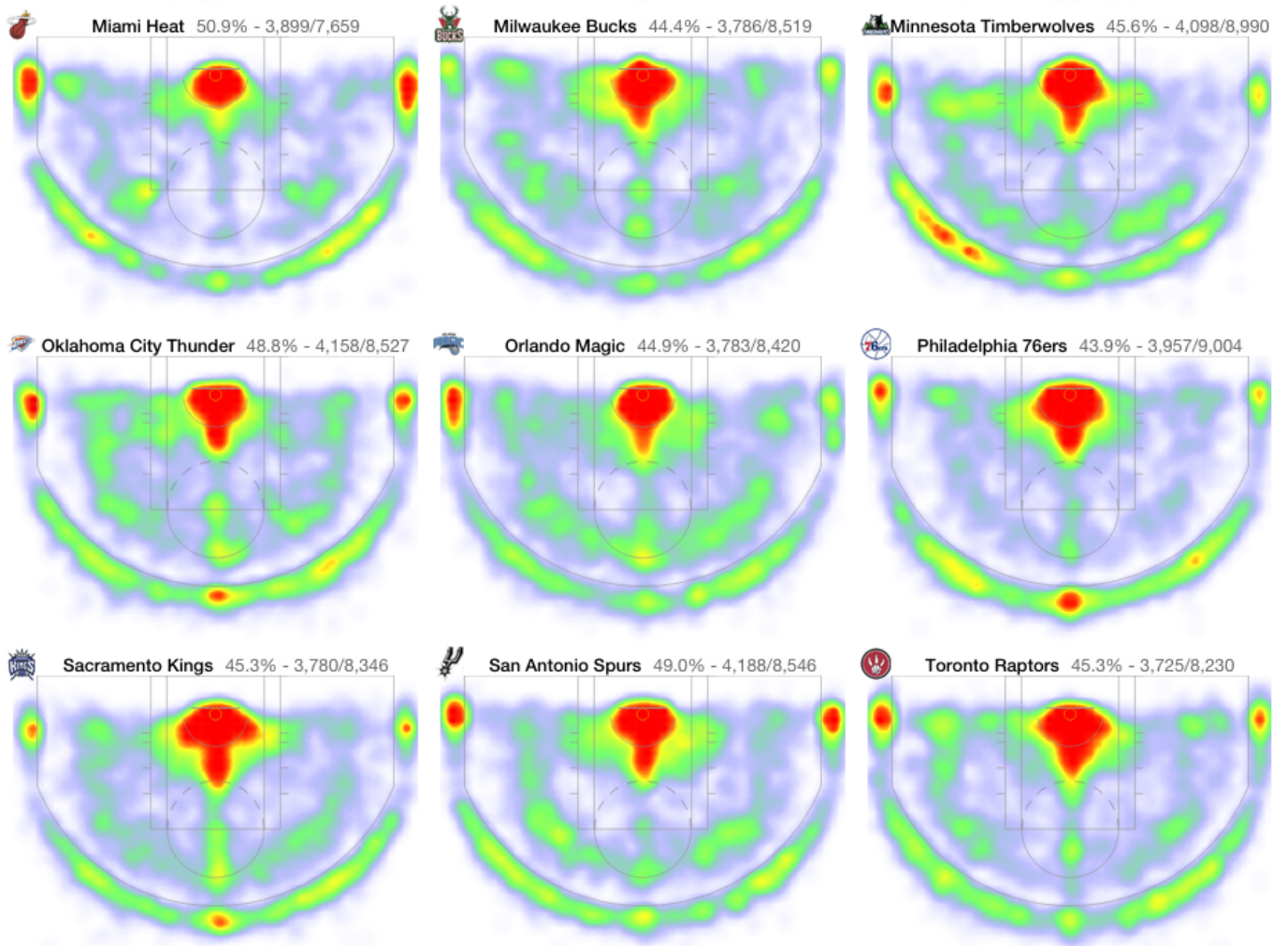


Fig. 38. Scenario: Miami, San Antonio, Toronto heat maps.