Sports Visualization: Using RPI Men's Hockey to Create Compelling Visualizations

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ABSTRACT

Even though the concept and acquisition of sports statistics has existed and been carried out for many years, visualization of sports data is relatively unexplored [10]. In this paper, the researchers create a sports visualization for RPI Men's Hockey that represents the data in various levels of exploration and provide a framework for similar visualizations. The visualization includes interactions such as expandable bars, mouse-over tool tips, and toggle switches. A user study was conducted to determine intuitiveness of the expandable bars and toggle switches. The study found that users understood clicking on the bars, but found navigating back to the top level of data less intuitive. Future work includes modifying the visualization based on user feedback and expanding the visualization to other teams and even other sports.

Index Terms: Sports Visualization, Hockey, SportsVis, Interactive, D3

1 INTRODUCTION

Even though the concept and acquisition of sports statistics has existed and been carried out for many years, visualization of sports data is relatively unexplored [10]. However, in recent years sports visualization has grown in popularity due to the large amount of heterogeneous data, real -life applications, and the ability to work closely with experts in the field [9]. Previously much of the data has existed in tabular form, which "requires significant cognitive effort" and makes it difficult for users to identify trends in the data [5].

College ice hockey is one area where comprehensive data visualizations have not been utilized, yet the data to produce them is available. In particular, a visualization that allows the viewer to examine the record-keeping of a program's history at several views of granularity does not currently exist. Instead, the majority of data is solely available in tabular format, which make comparison and identification of trends or anomalies extremely difficult.

In this paper, a visualization that allows exploration of sport statistical data at many levels is presented. The levels of exploration allow viewers to determine how a particular statistic is composed, providing a unique feature that many other sport visualizations do not include. In particular, the program history of Rensselaer Polytechnic Institute (RPI) Men's Ice Hockey will be visualized. The RPI Hockey program has been existence since 1901, providing over a century of data for visualization [12]. However, the framework of the visualization could easily be applied to other hockey teams or even another sport.

2 RELATED WORK

A variety of sports visualizations have been created through a wide range of sports, and data representations. Perin *et al.* presented a review of current challenges and advances in the sports visualization world. Hundreds of sports visualizations (both academic and non-academic) were examined and analyzed based on three types of data: box score (discrete in game), tracking (continuous motion), and meta (discrete data beyond one game) data. The paper outlined common features and considerations for each of these data sets and also gave examples of different types of visualizations. They conclude the paper by drawing interesting conclusions on the current gaps in research and other emerging sports visualization considerations [9].

One specific sport related visualization by Cox and Stasko [5] created a baseball data visualization from tabular data with interaction features such as zooming and filtering. Two visualizations are presented: the baseline bar display and the player map. The baseline bar display looks at data over the course of one season and is a very information dense display. It includes information such as win/loss, run margin, and runs scored by the team being visualized. It uses the visual attributes of length and color to present data to the user. The authors utilized these visual cues to take advantage of pre-attentive processing so viewers can easily detect patterns that occur over the course of a season. Additionally, viewers are able to employ filters to view statistics for games matching only specific criteria. The other visualization was the player map where, as the name states, individual player statistics are visualized. The authors use the visual cues of color and size to represent the relationship between two different statistics. In the discussion relating to this visualization type, the authors recommend using rate statistics versus counting statistics. This is because a player may have a high value counting statistic (e.g. goals in the case of hockey, hits in the case of baseball), but if they also have a large number of attempts (e.g. shots or at bats) [5].

T. Polk *et al.* present visualization for another sport: tennis. A novel system for tennis visualization aimed at non-professional tennis players was created. The user simply inputs a match video and some simple statistics. From this, players and coaches are able to gain insights into various statistical measures such as who had the serve, who won the point, how the point was won, and ease of the game (usually by match time). They are even able to click on data points and view the specific place in the video where the data is from. Visualization tools such as meters, grids and bar charts are used to present the data. A user study was conducted, with both players and coaches reacting favorably to the ease of use and information the system provided [11].

Similar to the visualization in this paper, Pileggi *et al.* explore visualizations in ice hockey analytics, specifically the NHL, where teams are using analytics, but not visualization. The authors collaborated with a professional hockey analyst who was considered the user throughout their exploration. With the analyst's assistance, the stages of exploring the data, discussing hypotheses about the data, and presentation of findings were identified to be highly important to these visualizations. This paper worked to visualize locations of shots taken during one NHL season at various arenas and looked at case studies of professional analysts using visualizations during analysis. Further, this paper works to explain how statistics are recorded within the sport of ice hockey. Hockey statistics are often

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taken manually, unlike other sports that may use technology such as computer vision to record statistics. Therefore, it should be noted that hockey statistics are not always extremely precise and this must be taken into consideration when creating visualizations [10].

3 Visualization Audience and Design Goals

In the following sections audience and goals for the visualization are presented.

3.1 Audience

The audience for this visualization involves three main groups: sports fans, players (current or prospective), and coaches. In general, sports fans are interested in learning facts about "their team" (in this case RPI Men's Hockey). This tool should help them discover interesting data points, trends, and other statistics they would not have otherwise discovered from the table based statistical recordings. Players could utilize it to see if they are on track to break a record or how they compare to players in the past. Likewise, prospective players could use it to understand a programs history and recent seasons statistics. Lastly, coaches could use the visualization to compare the current seasons to prior results to determine what statistics need to be improved for increased success.

3.2 Design Goals

Several design goals were determined before implementing the visualization.

- Users should be able to answer common questions (e.g. the top goal scorer in a season or all time, who holds the record for most penalty minutes, etc.).
- The visualization should be presented in a familiar and easy to read manner (e.g bar charts, line graphs, etc.).
- Trends and anomalies should be easily identifiable.
- Users should be able to locate a specific statistic in a short period of time (i.e. less than thirty (30) seconds).
- Interaction with the visualization should be intuitive and utilize common visualization interaction techniques.
- Both team-based and player-based statistics should be visualized.

4 Implementation

Implementation required two main stages: data acquisition and visualization. The implementation of both stages are detailed in the sections below.

4.1 Data Acquisition

Data for the visualization was obtained from three different sites: College Hockey News, The RPI Archives, and College Hockey Stats [3, 4, 12]. Initially, a Python-based web scraper was developed to collect information from College Hockey News. To create the web scraper, Python libraries including `selenium`, `BeautifulSoup`, and `pandas` were used. The data was scraped into comma-separated value (CSV) files.

However, there were still significant gaps in the data. Some of the information and statistic gaps were filled by exploring College Hockey Stats and the RPI Archives. Unfortunately, these resources were in the form of plain text and data had to be captured by hand. However, due to changes in the sport and what statistics were recorded, and the age of the program, gaps still remained in the data.

Once all the data was collected, the various data sources were combined into three CSV files: team statistics, player statistics, and goalie statistics. These CSV files were then converted into spreadsheet files using Microsoft Excel. With all data combined, additional statistics were also calculated from the data including information like team and goalie win percentage.

Finally, the data was converted to JavaScript Object Notation (JSON) format to be interpreted by the visualization code. Microsoft Excel was used to format each of the statistics into the correct JSON string. However, in order to maintain the data hierarchy, the formatted JSON strings had to be added to each statistics file by hand. In all, 55 different statistics were created. A full list of all the data acquired is shown below in Table 1.

Team	**Player Season and Career**
Team Average Save Percentage	Number of Assists
Number of Games Played	Number of Games Played Goalie
Number of Game Winning Goals	Number of Game Winning Goals
Number of Goals Against	Number of Goals
Number of Goals Scored	Goals Against Average Goalie
Number of Losses	Number of Goals Allowed Goalie
Number of Assists	Number of Minutes Played
Number of Points Earned	Number of Points Earned
Penalty Kill Percentage	Number of Saves Goalie
Number of Penalty Minutes	Number of Ties Goalie
Percentage of Games Won	Number of Wins Goalie
Number of Power Play Goals	Number of Penalty Minutes
Number of Short Handed Goals	Points Per Game Average
Number of Ties	Number of Power Play Goals
Number of Wins	Save Percentage Goalie
	Number of Short Handed Goals
	Short Handed Goals Allowed Goalie
	Shot Percentage
	Number of Shots
	Win Percentage Goalie

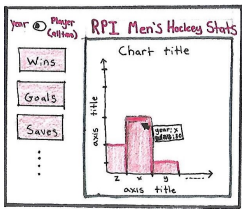
Table 1: List of the statistics gathered through data acquisition.

One of the largest data acquisitions challenges was missing data values. Since the RPI Men's Hockey program has been around since 1901, there are many gaps in the program, especially in earlier years. In-depth team data was not recorded until the late 1950's and thorough player data was not taken until the late 1990's. Trying to fill in these gaps through research presented a significant challenge and a lot of the data could not be acquired.

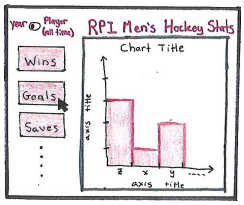
4.2 Visualization

To come up with an initial design that aligned with the design goals, storyboarding was completed as shown in Fig. 1. As the storyboard shows, the visualization is presented in a common graphical format, bar charts. The decision was made to utilize bar charts to represent the data as this form of data visualization is familiar to a wide audience. According to [6], bar graphs also help the user more easily identify trends. Fig. 1a shows a mouse-over feature, in which a tool tip showing the value of the bar appears. This allows users to more quickly identify the value of the statistic they are looking at instead of having to rely solely on the y-axis. Fig. 1b shows users navigating the visualization through buttons, a common and familiar way to navigate web pages and other applications [1]. Additionally, as seen in Fig. 1c, both player-based and team-based statistics will be visualized with a toggle switch being used to switch between the two. Finally, a key aspect of the visualization is proposed in Fig. 1d, where users can click on a bar to expand it, exposing what that particular statistic is composed of (e.g. how many goals each player scored that season).

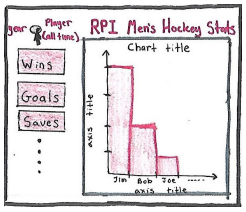
Due to the high level of interactivity desired as well as the need for the visualization to be quickly and easily accessed over several different platforms, `D3.js` was selected as the main library for the



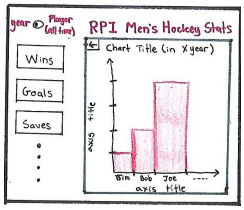
(a) User can mouse-over a bar to activate a tool tip showing the value.



(b) Users will interact with the visualization via buttons



(c) A toggle switch will be included to switch between team-based and player-based stats.



(d) A user can click a bar to reveal how that statistic is composed.

Figure 1: Hand-drawn storyboard.

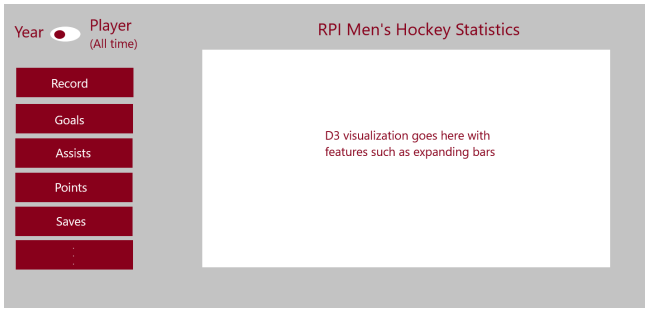


Figure 2: A mock-up of the hand-drawn design.

visualization. `D3.js` provides several visualization tools within web browsers, allowing it to easily be integrated into a new or existing web page [7].

Before implementation began, a more formal mock-up of the visualization was created, as shown in Fig. 2. This mock-up design consists of a single toggle to switch between team and player statistics, buttons to switch between the different statistics, and a single chart area where vertical bars with expanding functionality would be shown. This expanded upon the original storyboard by selecting an initial color palette, based upon RPI's school colors, that could be used during implementation.

After this mock-up was created, some initial feedback was received. While some enjoyed that the data set was RPI themed, others questioned whether this visualization needed to be RPI-specific or if it could be generalized. The team decided to move forward with an RPI-specific implementation, but designed the framework of the visualization such that the visualization could represent another team with minimal modification to the code. Further, it was questioned if users would be able to filter which years are shown. For simplicity reasons, it was opted to not add another control for selecting years, and instead always display data for the entire program history (1901 - 2019). Additionally, for player-based statistics, only the top 25 players (more if ties existed) would be shown as to not overwhelm the user with too much information.

With this initial design and feedback in mind, implementation began, starting with the basic functionality of the chart area in-

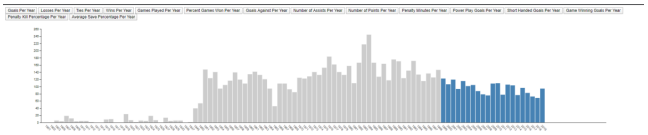


Figure 3: Base visualization with vertical bars and no styling.

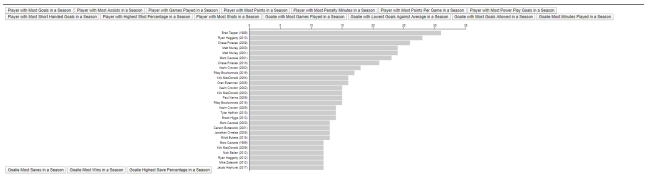


Figure 4: Base visualization with horizontal bars and no styling.

cluding expandable bars, toggle switch, buttons, and the bar chart itself . The toggle switch and buttons were both implemented in HTML and CSS. To implement bar expand-ability, the capability of `D3.js`'s `hierarchy` was utilized. `hierarchy` allows for parent-child(-grandchild, -etc.) relationships to be defined for the data. For example, for the "goals" statistic the structure would be: a root node that is parent to every season and each season node is a parent to all of the players on the roster that year. Each node contains a label and a value (in this example, goals) which is used to display the correct information on the chart, depending on which level of the hierarchy is shown. In this visualization, the parent node value is the aggregated value of its children's values. In the "goals" example, the value of the parent would be the total goals for that season, while each of the children would be how many goals that specific player scored during that season. Bostock was used as a reference for how to display the hierarchical structure in bar chart format. While Bostock displays horizontal bars, with a few code modifications, it is able to display vertical bars [8]. These features were implemented in an initial base visualization without any styling as shown in Fig. 3. Additionally, data was properly sorted with year-based sorting for team statistics (low-high) and value-based sorting for player statistics (high-low).

This basic visualization identifies the expandable bars via a blue color. Once this was implemented, it was discovered that the initial design had to be modified. First, it was determined that, in order to show all of the data, the width of the chart area must be extremely wide. This meant there was no room for the button interface to be displayed on the side as originally proposed. Therefore, the buttons needed to be moved either above or below the visualization. For aesthetic reasons, the decision was made to move them below the visualization. Likewise, the toggle switch was moved to be directly above the button controls. Additionally, it was realized that the player data was not displayed in the optimal format for accurate interpretation. According to [6], horizontal bars would be a better representation of the ranked (by value) player data, while the year-ordered team data should remain in vertical bars. Therefore, it was decided to add a second set of axes (for horizontal bars). The two different sets of axes would switch with the year/player toggle. The horizontal set of axes is shown in Fig. 4.

After implementing the basic functionality of the chart, including switching between data displayed, tool tip functionality was added to display the value of the bar. Additionally, functionality was added to change the color of the bar when moused-over to help distinguish the bar from those around it. Further, a HTML and CSS page for this visualization was created with a description of the visualization

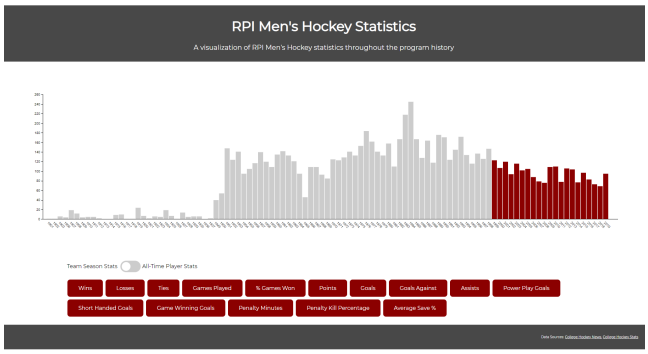


Figure 5: The styled visualization.

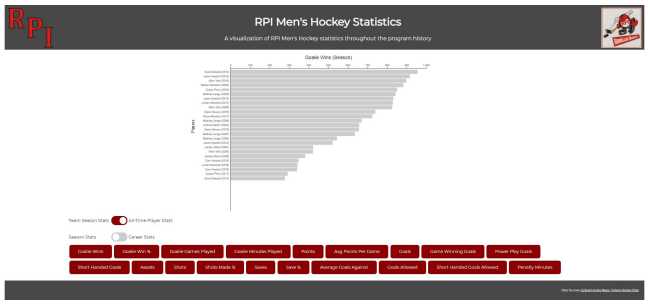


Figure 6: Added chart labels and secondary toggle to switch between season and career statistics.

and data source links. However, instructions were not included on this page as the researchers aim for the visualization to be intuitive enough alone. The completed styling is shown in Fig. 5.

Compared to the original design, in addition to the aforementioned modifications, there was also a change in the coloring of the visualization. Instead of having a gray background with a white chart area, it was determined that it looked best to have a mostly white background with a darker header and footer anchoring the whole visualization.

After completing the styling of the visualization, it was determined there were still a few missing aspects of the design. First, the charts were missing axis labels and titles and so it was difficult for the user to know which statistic he or she was looking at and what the *y*-axis represented. Labels were added to more clearly identify the data being displayed. Secondly, it was realized that there are two categories of player statistics: season and career. Instead of having twice as many button controls for the player statistics, a secondary toggle switch that only appears for player statistics was added. This toggle allows the user to change between season and career all time statistics. The secondary toggle switch was designed so that that the user stays on the same statistic when the season and career toggle was switched to make comparison easier and to maintain continuity between the two sets of data. For example, if a user has selected the goalie win percentage statistic and the toggle switch is currently in the season position, flipping the toggle brings the user to career goalie win percentage and vice versa. However, this same continuity could not be implemented for the primary toggle switch as there is not a one-to-one correspondence between team and player statistics. A view of this updated functionality and some further RPI theme-ing is shown in Fig. 6.

Due to the extreme width of the season chart, the visualization has limited use on smaller screens and will fail to scale as continued

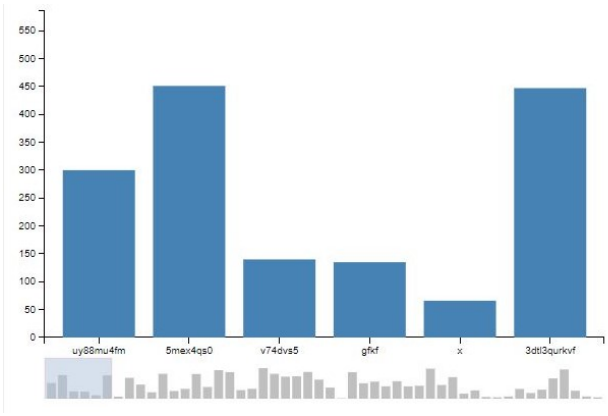


Figure 7: Example scroll bar feature with overview [2].

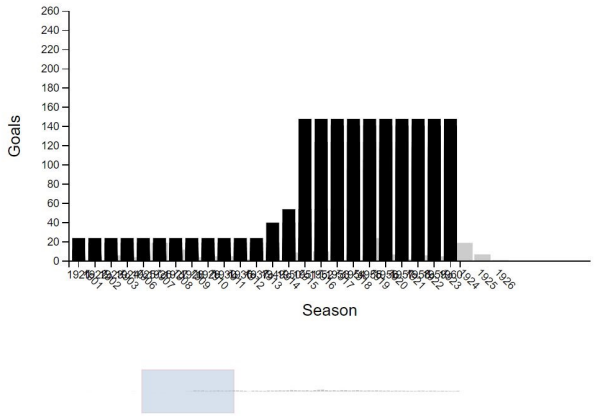


Figure 8: Implementation challenges faced while adding the scroll bar.

seasons expand the data set. To attempt to alleviate this problem the researchers tried to implement a scroll bar for the char itself, similar to the one shown in Fig. 7 [2]. A scroll bar such as this one was preferable as it provides a secondary set of axes that continues to allow the user to see a general overview of the data, so long term trends or anomalies are still identifiable.

However, the researchers faced difficulties implementing this feature in combination with existing features such as the entering, exiting, and transitions the bar chart due to the hierarchical structure. During implementation, the team faced several issues such as those seen in Fig. 8.

Due to limited time, the team saved the scroll bar implementation for future development. Views of the final visualization can be seen in Fig. 10 and Fig. 11 in Appendix A and a live view of the visualization can be found at `http://homepages.rpi.edu/~crooks/rpiHockey`.

5 User Study

A user study was conducted to gauge users reactions to the visualization and to determine how users react to clickable bar charts. The specific question the researchers wanted to answer was: “how will users react to clickable bars and toggles? Is it intuitive? Confusing or hidden?” The researchers hypothesized that the users would understand clicking on the bars, but not going back up to the top

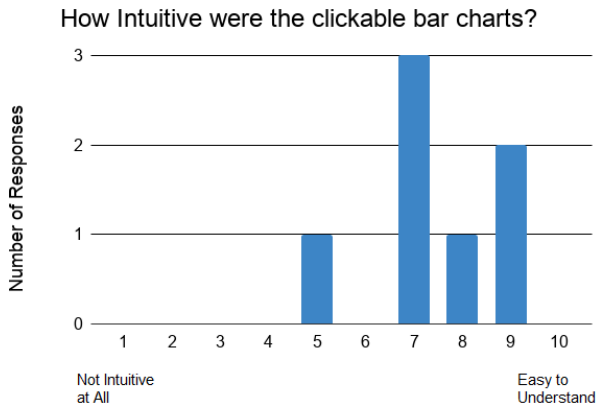


Figure 9: Shows how intuitive users found the clickable bar charts on a scale from 1 - 10 with 1 being not intuitive at all and 10 being very intuitive. The trend shows that participants found the clickable bars fairly intuitive. The mean score of the data was found to be 7.43 and the median was found to be 7.

level of data. The researchers also hypothesized that users would understand the use of the toggle bars.

The visualization was hosted on one of the researchers personal websites. Participants were instructed to navigate to the visualization on their favorite web browser. They were then instructed to click around and investigate the visualization for five (5) minutes before answering a series of questions on a printed questionnaire or through a google form. The questionnaire can be found in Appendix B. There was no time limit on how long participants could take to answer the questions.

The participants were first asked to answer a series of demographic questions (name, gender, age, education level). To test the ability of users to find data using the clickable bars, participants were asked to find a specific player statistic (number of goals scored by Mark Yurkecz in 2004). Afterwards, participants were asked on a scale of 1 to 10 (with 10 being the highest) how intuitive they thought clicking on the bars to view the data and then clicking the chart area to go back up was. The users were then asked a series of three yes or no questions to gauge their interaction with the visualization including: did you explore the toggle switch to view more data, did you think the visualization was missing any statistics, and did you find the visualization memorable. To conclude the study, users were asked to provide any additional comments they may have had.

5.1 Participant Profile

7 total participants completed the study. There was an age range of 18 - 72 years old with approximately 57% males and 43% females. All participants had at least some college education. It must be noted that only 2 of the participants represented our target audience. These two considered themselves RPI Hockey fans. Other participants were neither fans, players, nor coaches. However, these other 5 participants still gave invaluable feedback.

5.2 Results

Only one of the participants incorrectly identified the correct number of goals for the player (Mark Yurkecz), while the rest (86%) correctly identifying the correct number of goals scored as 1. A graph showing the scores of bar clicking intuitiveness is show in Fig. 9.

The mean score was found to be 7.43 and the median was found to be 7. It was found that the lowest score was given by the oldest participant. However, further study is necessary to determine if the trend with participant age is statistically significant.

All participants reported having interacted with the toggle switches and all participants believed the visualization was not missing any statistics. However, only 86% (all but one) of participants thought the visualization was memorable.

When considering the comment section feedback, some users did not like the color and wished it was “more vivid” or there was more colors “to indicate special seasons (Nat’l Championships, ECAC championships, etc.).” Others commented it was easy to click on the bars, but wished there was a back button instead of having to click on the chart area to go back. Lastly, people suggested making the animations shorter. They were eye catching but many users found them “gimmicky”.

6 Conclusions

From the results of the study, the team tentatively accepts their first hypothesis that users will understand clicking on bars, but not going back. From the comments provided during the user study, participants found that clicking on the bars was fairly intuitive, but struggled with returning to the parent level of data. If an additional, more extensive and representative, user study was completed after modifications were implemented, a median score of approximately nine (9), with 10 being very easy to use, would be required to reject the hypothesis. The team also tentatively accepts their hypothesis that users would understand the toggle bars. All participants reported being able to easily navigate through with the toggles and look at the different data views (team, player season, player all time), but this was not explicitly confirmed in the study. Larger, more extensive studies are needed to officially accept our hypothesis.

From the study the team also identified other key areas of possible improvement including colors and animation. These features require exploration to determine whether their modification would make a more satisfying user experience. However, like with the hypotheses, further study is needed to assess these possible changes and to identify other areas of improvement for the visualization.

Through this research, the researchers created a compelling visualization for sports visualization with data from the RPI Men’s Hockey Team. Additionally, this visualization provides a framework upon which statistics from other teams or even other sports can be visualized in a simple manner while allowing trends and anomalies to be identified as along with the composition of a statistic.

7 Future Work

In the future, there are several possible enhancements that the authors would like to explore. First, the design of the visualization should be improved based on the user study feedback. This includes tasks such as modifying animations, considering the possibility of a back button or other navigational features, and looking into indicating championship years to the viewer in some manner. Additionally, the inclusion of a scrolling system would allow for further extension in terms of data and expand screen sizes that can properly view the visualization. This feature would also allow the user to focus on a subset of consecutive years while maintain an overview of the data (which is a key feature of the visualization). Further, significant gaps in data were discovered when acquiring statistics on RPI Men’s Hockey. The visualization could be enhanced by reaching out to RPI resources such as the team itself or the RPI Archives which may provide an additional data source to fill in the gaps in the data.

In addition to the aforementioned features, there is also the possibility to further expand the visualization in other ways. This includes visualizing for other teams such as the RPI Women’s Hockey team, other Eastern College Athletic Conference (ECAC) teams, or other hockey teams. The visualization could also be extended to other sports such as soccer, basketball, baseball, etc. with little modification.

Lastly, a larger user study, with participants more representative of the target audience, could help gain a better understanding of what features are needed from the visualization.

8 Acknowledgments

The authors thank Dr. Barbara Cutler for her guidance and support throughout the project. Additionally, the authors thank all those that provided feedback to improve the project along the way.

9 Work Breakdown

Savannah Crooks was mainly responsible for the data acquisition and organization. She created the web scraper to acquire a majority of the data. She also went through plain text files and added additional data by hand. She also calculated additional statistics and created all the JSON files with the statistical data.

Both Emily Veenhuis and Savannah Crooks worked together to get the base `D3.js` functionality working including the expandable bars, and buttons. Additionally, both members worked on the scrollable bar that was never successfully implemented. Both members also both worked on the final presentation and final paper.

Emily Veenhuis was mainly responsible for creating the user interface (UI) and interactive-ness for the visualization. She worked to create the toggles to switch between data. She also created the color scheme and added labels and mouse over capability.

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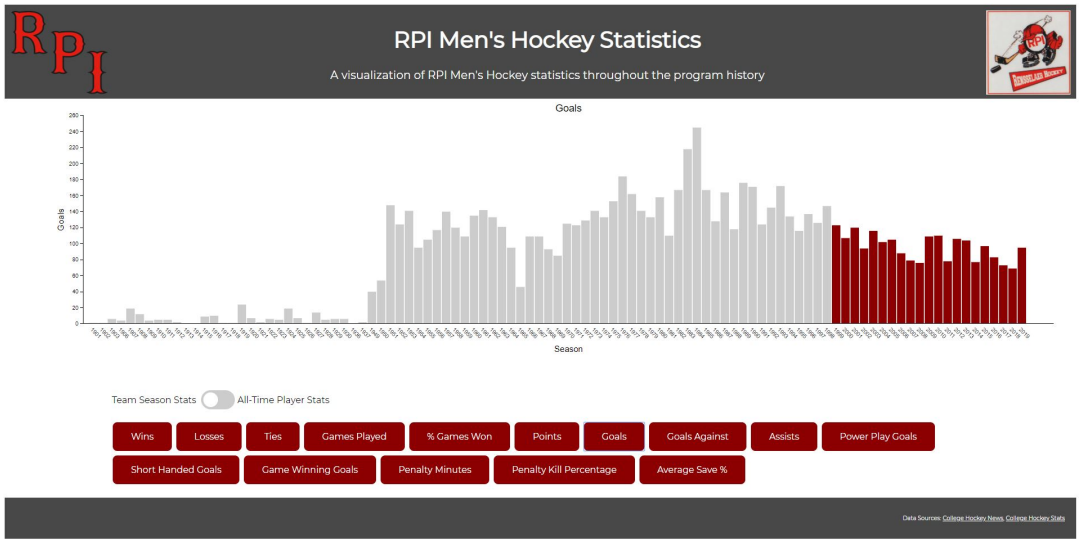
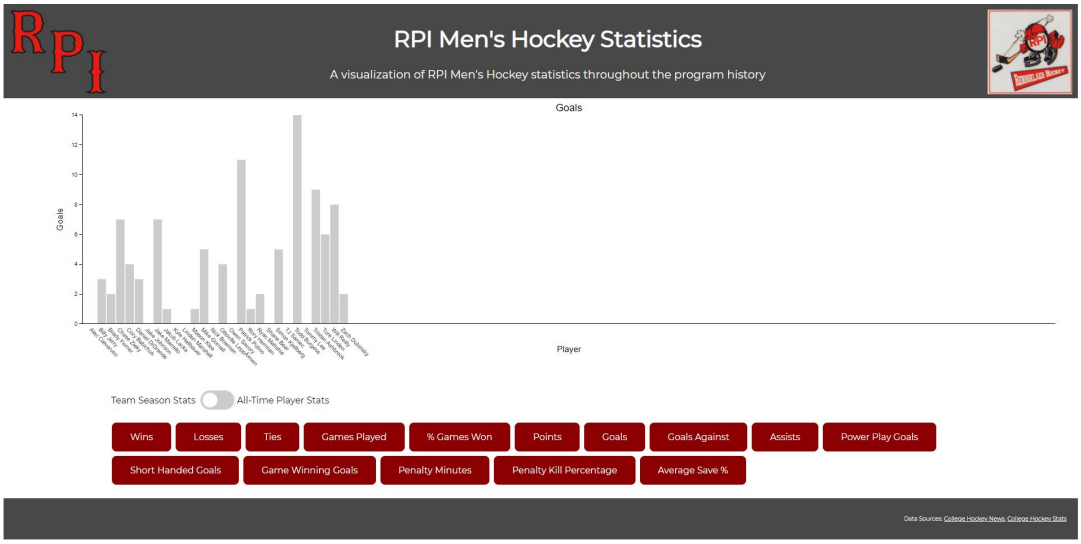
A Final Visualization

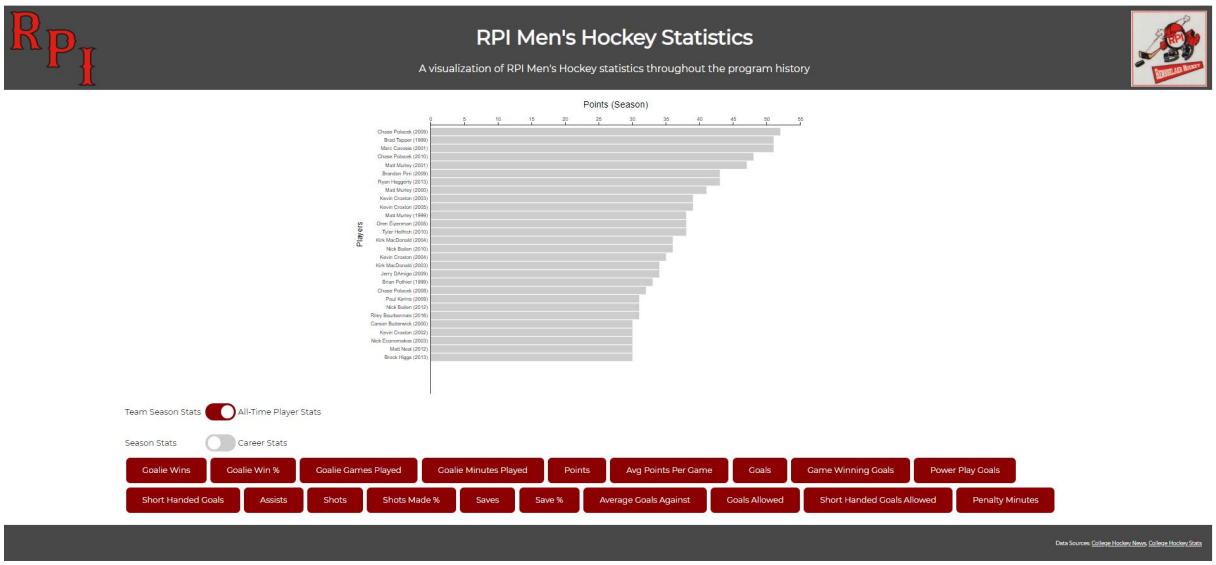


(a) Shows the team season stats view with the number of goals statistic selected.

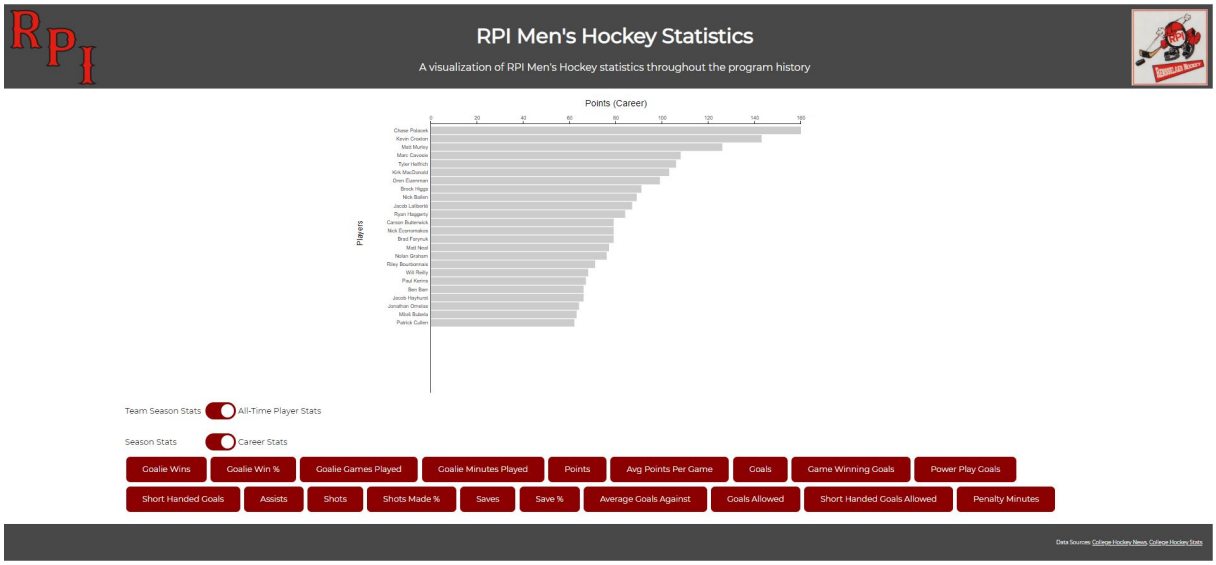


(b) Shows the team season stats view with the number of goals statistic selected and the 2019 bar chart selected to show the players on the team and how many goals each of them scored.

Figure 10: Screenshots of the final visualization showing the team view.



(a) Shows the player season stats view with the number of points statistic selected.



(b) Shows the player career stats view with the number of points statistic selected.

Figure 11: Screenshots of the final visualization showing the player view.

B User Study Questionnaire

RPI Men's Hockey Visualization Questionnaire

Thank you for agreeing to be part of the case study for our visualization on RPI Men's Hockey data. By participating in this study you are agreeing to have your anonymized answers and data shared publicly. This should only take about 10 minutes but feel free to interact with the visualization for as long as you would like. Please explore the visualization for 5 minutes before answering the questions.

1. Participant Name:
2. Gender [circle one]: Male Female Other/Prefer Not to Say
3. Age:
4. Highest Level of Education Completed [circle one]:

   High School GED Some College Associates Bachelor's Doctorate Other

   If other, explain:
5. The visualization was eye catching and drew you in [circle one]:

   Strongly Disagree Disagree Agree Strongly Agree

   Comments:
6. How many how many goals did Mark Yurkewecz score in 2004?

   Answer:
7. How intuitive is clicking on the bars to view the data and then clicking the chart area to go back up on a scale from 1-10 [1 being not intuitive at all, 10 being very easy to understand]?

   1 2 3 4 5 6 7 8 9 10

   Comments:
8. Did you explore the toggle switch to view more data [circle one]? Yes No
9. Did you think the visualization was missing any statistics [circle one]? Yes No

   What statistic(s) was it missing?
10. Did you find the visualization memorable [circle one]? Yes No
11. Additional comments: