From Data to Narrative: An Intuitive Software Solution for Statistical Process Control Chart Creation, Exploration, and Storytelling

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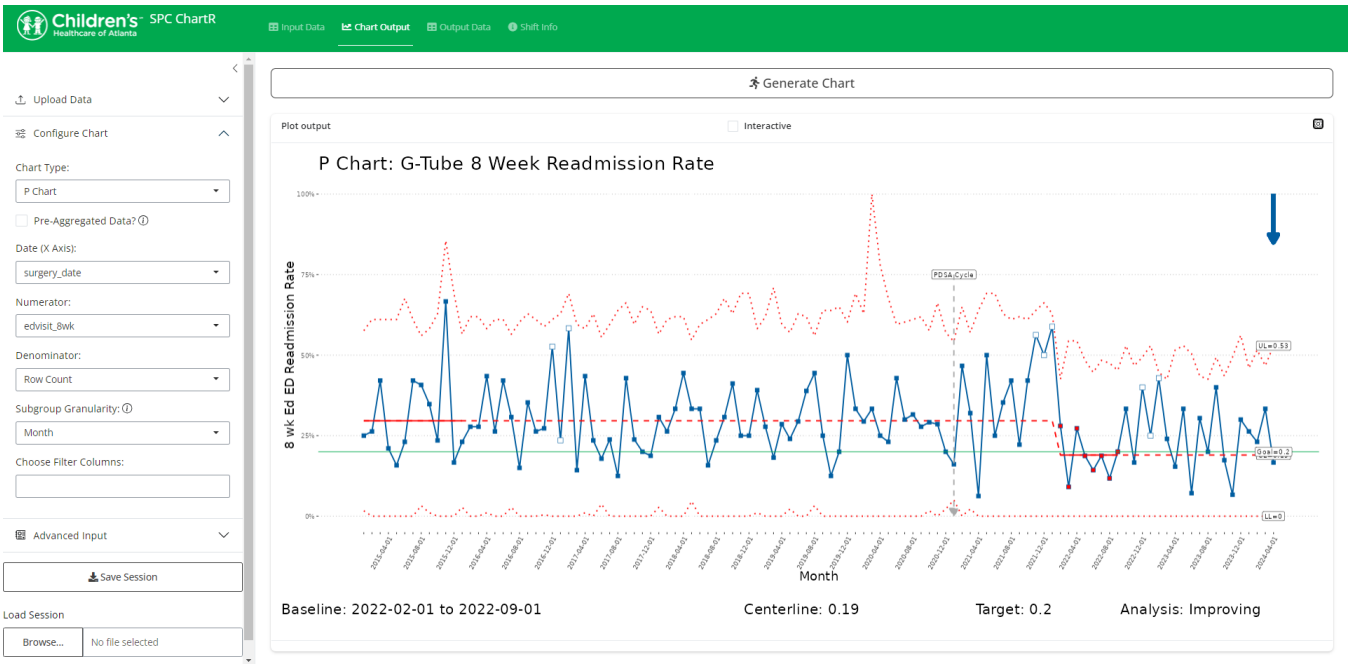

Figure 1: Generating a P Chart with SPC ChartR

Abstract

Healthcare Quality Improvement (QI) frequently employs Statistical Process Control (SPC) charts, but current tools are cumbersome, requiring extensive expertise and manual data manipulation. Our SPC ChartR software streamlines SPC chart generation, enabling intuitive exploration and contextual storytelling. This system offers an innovative solution for both experienced QI professionals and clinicians with limited data literacy, and it enhances data visualization efficiency as validated by substantial task completion rate improvements and a high System Usability Scale score.

1 Description of the Problem

Statistical Process Control (SPC) charts have long been an academic and industry standard for Quality Improvement (QI) visualization in healthcare [1]. Current SPC visualization tools necessitate significant knowledge of QI methodology to select and interpret the appropriate chart, require extensive data preparation, rely on antiquated workflows, and do not leverage advanced data processing for automated insights. Moreover, these tools seldom incorporate contextual analysis, external knowledge integration, and user-friendly data exploration in conjunction with efficient SPC chart creation. To bridge this gap, we introduce SPC ChartR, an innovative software built with open-source tools that simplifies the SPC visualization process, facilitating the journey from raw data to insights across a broad spectrum of applications.

2 Methods

Dashboard Design: For the core functionality of control limit calculation, we relied on QI literature to ensure compliance with the correct control chart rules and standards and to account for all features necessary in SPC software [2]. We then employed human-centered design beginning with a user and task analysis in collaboration with QI Specialists, informaticists, data experts, and clinicians to understand how control charts fit into their

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workflow and where we could add value. These insights were incorporated into a functional prototype to automatically generate control charts from an arbitrary dataset.

Usability Testing: We conducted five rounds of scenario-based usability testing with health system employees who all use SPC charts but vary in their job responsibilities, level of QI and analytics expertise, and control chart workflow. For each round of usability testing, we began with a brief overview of the application and a basic tutorial of the core functionality. We then asked the user to provide a data set and walk us through a recent scenario where they needed to generate a control chart. Next, we asked the user to generate the required control chart twice: once with our application, and once with their existing workflow. We aimed to provide psychological safety with a focus on testing the software rather than the user as the user worked through each scenario [3]. For each run-through, we measured the time-to-completion and noted any issues the user encountered with our application. At the end of the usability test, we solicited feedback and feature requests to improve the application, and the user completed a thirteen-question survey to gauge their profile as an SPC user and calculate the application's score on the System Usability Scale (SUS) [4]. We conducted the tests following the principles of formative usability testing, updating the application between tests to improve usability and functionality.

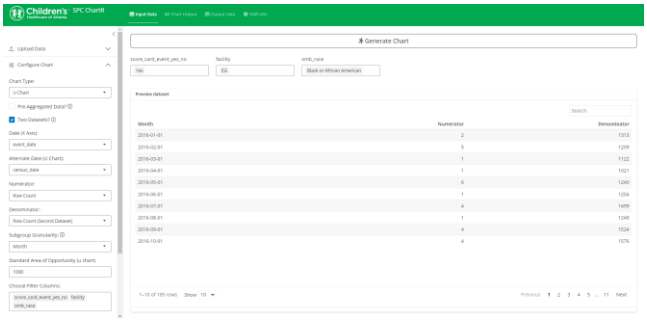

Figure 2: Data exploration in SPC ChartR

3 Results

Users and Tasks: We identified two main user roles: (1) improvement specialists (e.g. QI specialists, data scientists, clinical informaticians, and researchers) whose primary job involves QI or research and creation of SPC charts and (2) improvement participants (e.g. clinicians) who contribute to QI. Improvement specialists generally had access to a dedicated SPC tool (most commonly QI Macros followed by scripts in R or python), while improvement participants often had no tools or static MS Excel templates for specific SPC types. Our task analysis identified:

- Exploration (Figure 2): Dynamic filtering and Grouping
- SPC generation (Figure 3): User-selection of columns and chart type, Adjustable centerline shift/special cause rules, Ability to include/exclude points and force or suppress centerline shifts, Progress checkpoints, and Output data for further processing in additional tools.
- Visual storytelling (Figure 4): Date-specific annotations, Target line, Improvement direction arrow, Automated/manual interpretation, Readable centerline shift/special cause explainer.

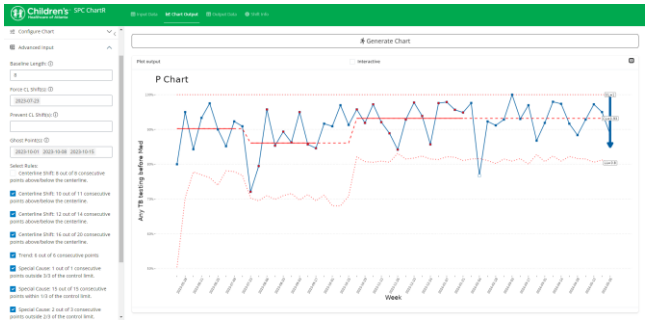

Figure 3: Forced shifts, ghosted points, and custom shift/special cause rules in SPC ChartR

Usability Testing: Of the five users we worked with (two physicians, two nurses, and one QI Specialist), four had significant experience generating their own SPC Charts, three had access to the proprietary QI Macros software currently used to generate SPC charts at our institution, and one had experience visualizing data with statistical software. Our prototype demonstrated significant improvement over existing workflows by all metrics that we collected. Of the five selected users, one had no way to generate SPC charts on their own with their current workflow, while all five were able to generate the SPC chart they needed with our application, representing an improvement in task completion rate from 80% (4/5) to 100% (5/5). Among those who were able to generate an SPC chart, average time to completion was 5 minutes (range: 3-8) with the new application and 11 minutes (range: 1-19) with existing workflows. SPC ChartR averaged a score of 86 (range: 67.5-92.5) on the System Usability Scale (SUS). Notably, all participants responded with "Strongly Agree" to the prompt "I intend to use this tool to create SPC charts in the future." We also received strong qualitative feedback throughout usability testing; a physician user stated "This is going to save me several hours per week of work. I definitely prefer the output of this as compared to anything I'm doing by hand right now," and an anonymous user stated that they "look forward to hearing more about this tool and hopefully using it in the future."

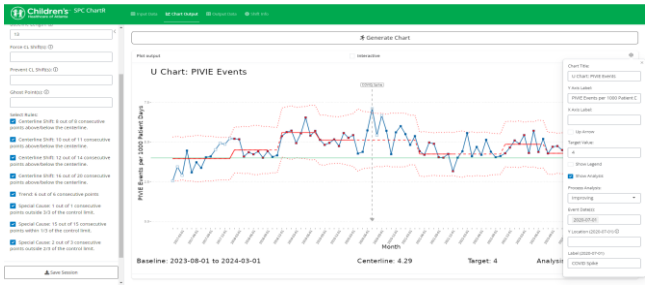

Figure 4: Visual Storytelling in SPC ChartR

4 Discussion

SPC ChartR offers an accessible and streamlined pipeline that enables users with diverse analytical skills to transform raw data into a coherent narrative that effectively measures and depicts changes or stability in processes over time for quality improvement. SPC ChartR was associated with substantial improvements in time on task. This improvement is particularly notable considering users had extensive experience with their existing workflow but had never seen or used our tool before the test; we expect the difference to widen as users gain familiarity with our tool. Further, because users provided these tasks with their existing workflow in mind, we anticipate additional improvement in tasks designed to take full advantage of our software's novel capabilities, including on-demand filtering, aggregation, and annotation.

Thus far, users without access to commercial SPC software have been the most eager to adopt our tool in their visualization workflows given the large potential for efficiency gains. Components of SPC ChartR have also been used by data scientists and analysts to develop project-specific QI dashboards, ad-hoc reporting to quality leadership, and day-to-day data exploration. Further adoption by users with access to QI Macros will require adapting the functionality and interface to match their current workflow while enabling them to take full advantage of the application's new functionality. Future directions include facilitating database connections and further improving usability, particularly for the data upload and chart selection processes.

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References

[1] G. Suman and D. Prajapati, "Control chart applications in healthcare: a literature review," International Journal of Metrology and Quality Engineering, vol. 9, p. 5, 2018.

[2] L. P. Provost and S. K. Murray, The Health Care Data Guide: Learning from Data for Improvement. John Wiley & Sons, 2022.

[3] R. M. Schumacher and S. Z. Lowry, "NIST Guide to the Processes Approach for Improving the Usability of Electronic Health Records," US Department of Commerce, National Institute of Standards and Technology, 2010.

[4] J. Brooke, "SUS-A quick and dirty usability scale," in Usability Evaluation in Industry, vol. 189, no. 194, pp. 4-7, 1996.

[5] R Core Team, "R: A Language and Environment for Statistical Computing," R Foundation for Statistical Computing, Vienna, Austria, 2024. [Online]. Available: https://www.R-project.org/