

Towards Real-time Visual Exploration of Multiple Pairwise Meta-analysis Results of Clinical Outcomes

Huan He ^{1*}, Irbaz Bin Riaz ^{2,4,5*}, Syed Arsalan Ahmed Naqvi ², Rabbia Siddiqi ³, Noureen Asghar ³, Mahnoor Islam ³, M. Hassan Murad ⁴, and Hongfang Liu ^{1,†}

¹ Department of AI and Informatics, Mayo Clinic, Rochester, MN, USA

² Department of Oncology, Mayo Clinic, Phoenix, AZ, USA

³ Dow University of Health Sciences, Karachi, Pakistan

⁴ Mayo Clinic Evidence Based Practice Center, Mayo Clinic, Rochester, MN, USA

⁵ Mass General Brigham Hospital, Harvard Medical School, Boston, MA, USA

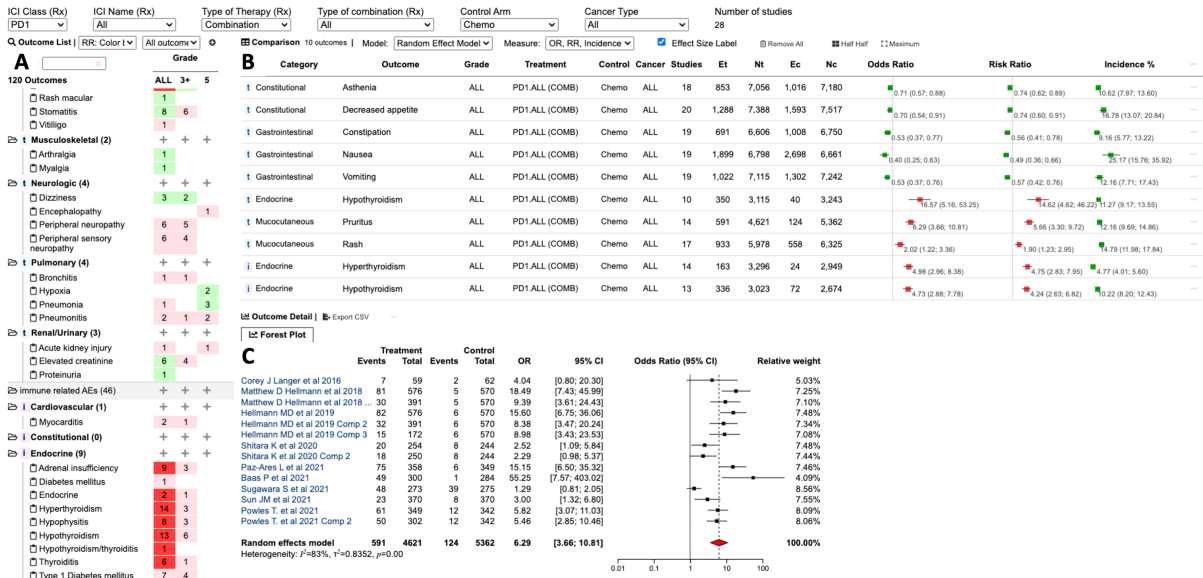


Figure 1: The screenshot of our proposed visual analytics tool including (A) an outcome list showing filtered outcomes, (B) a comparison view showing the PWMA results of selected outcomes, and (C) a detailed view showing a forest plot of a selected outcome.

ABSTRACT

An interactive and balanced presentation and interpretation of results from a pairwise meta-analysis (PWMA) can immensely facilitate evidence synthesizing in clinical research and practice. However, exploring the PWMA results for clinicians and researchers is challenging as the complexity of clinical questions increases and the vast number of involved studies and outcomes. In response, we proposed a web-based visual analytics system to facilitate the real-time exploration of massive PWMA results.

1 INTRODUCTION

Pairwise meta-analyses (PWMA) are widely used to summarize precise estimates of treatment effects by pooling evidence from randomized controlled trials that compare two interventions [1]. Several software such as STATA, RevMan, JASP, and OpenMetaAnalysis are available to perform PWMA. By using these tools, the meta-analysis results synthesized from massive datasets can be visualized as static tables and figures which are

usually published on journals and websites. However, interactive exploration of those results remains a significant challenge.

Firstly, existing tools can only be used locally for personal use and cannot be leveraged directly for further exploration of the online results. While the open-source R libraries such as meta [2] and metafor [3], can be integrated to serve PWMA through a web server, it also requires technical expertise to develop the web services. Secondly, when analyzing and exploring hundreds of outcomes at the same time (e.g., many adverse events), traditional analyses take considerable time, and thus users cannot get instant feedback in the setting of interactive meta-analysis.

To address these limitations, we propose using visual analytics to develop a web-based tool, which aims to provide a real-time exploration of multiple PWMA results.

2 RELATED WORK

A variety of commercial software and open-source packages are available to perform PWMA, such as meta [2], metafor [3], and dmetar [4]. However, there are a few studies focusing on PWMA visualization designs, such as forest plots and funnel plots, and they mainly focus on producing static figures and tables for publications. Compared with existing studies, our proposed visual analytics system aims to provide a more interactive way to help users explore the PWMA results of multiple outcomes of dynamic scenarios in a web browser in real time.

* Those authors contributed equally to this work.

e-mail: He.Huan@mayo.edu

e-mail: riaz.dr@mayo.edu

† e-mail: Liu.Hongfang@mayo.edu

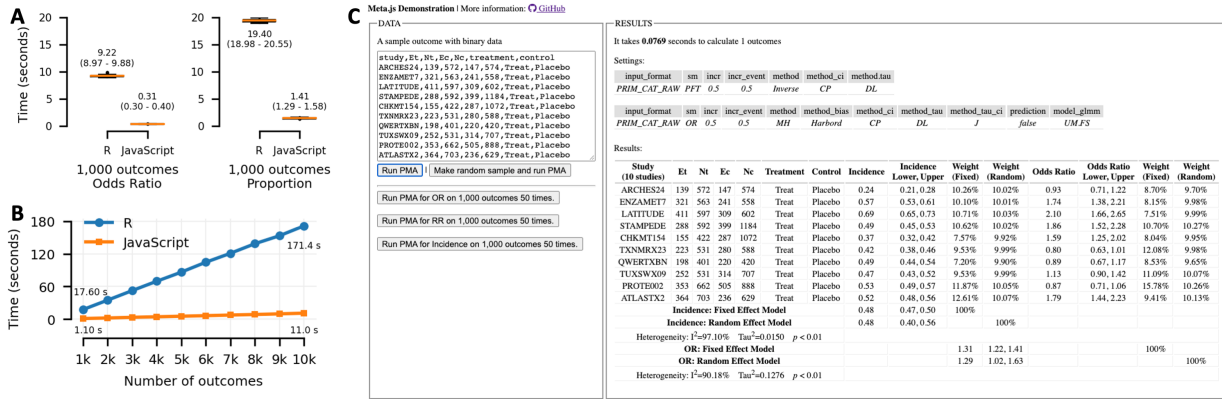


Figure 2: (A) The time cost comparison of the odds ratio and proportion calculation of 1,000 outcomes between R and JavaScript. (B) The comparison of the time cost of proportion calculation as the number of outcomes increases. (C) The screenshot of the web API shows the data format and real-time calculation results.

3 REAL-TIME PAIRWISE META-ANALYSIS

To obtain the PWMA results in real-time, we adopted a serverless architecture to design the system, which removes the need for a traditional always-on server and incorporates third-party services to provide computation abilities [6]. We developed a lightweight JavaScript PWMA module that can run in the user’s local web browser, which is optimized for specific PWMA tasks, such as the fixed effect estimator of odds ratio with heterogeneity (Fig. 2C).

As no server is involved, no time is spent on data transfer between the browser and server, and the user interface can get instant PWMA results for visualization. To evaluate the performance, we conducted two experiments, 1) calculation of the fixed effects on randomly selected 1,000 outcomes and 2) calculation of the fixed effects of a different number of outcomes. In both R and JavaScript versions, the test dataset is pre-loaded, and the calculation time is recorded. The source code of our lightweight JavaScript PWMA module and the visual analytics system with technical details are available in our GitHub repository for online demonstration (<https://ohnlp.github.io/Meta.js/>).

4 VISUALIZATION DESIGN

By following the agile software development process and Munzner’s nested model [5], we summarized the task requirements and design rationales to guide the development. Figure 1 shows a screenshot of our proposed system, which consists of multiple views, including (1) an outcome list (Fig. 1A), (2) a comparison view (Fig. 1B), and (3) a detailed view (Fig. 1C).

The outcome list (Fig. 1A) shows the macro-level distribution of the pooled effects of the outcomes in a specific scenario. This view has two panels. The filter panel provides a set of associated filters for users to customize clinical scenarios for conducting PWMA and the outcome panel shows the available outcomes and the summary of the PWMA results of a specific scenario in a tree-like table. In this view, the green color represents relative benefit while the red color represents relative harm, and the darker color represents statistically significant results while the lighter color represents non-significant results.

The Comparison View (Fig. 1B) aims to support the comparison between selected outcomes to answer clinical questions. The major PWMA results of selected outcomes are listed and color-encoded row by row. The user can add outcomes by clicking the arc or cell in the outcome list. The same outcomes from different scenarios can be added for comparison. Users can click on each cell to check more information in the Detailed View.

The Detailed View (Fig. 1C) provides a customized forest plot to help users to examine the precision and spread of the studies

included for a specific outcome, and how the pooled effect related to the observed effect sizes.

5 CONCLUSION

As shown in Figure 2A, our lightweight JavaScript PWMA module shows significant performance improvements compared to the R version, which can enable real-time visual exploration of many outcomes. Moreover, as the number of outcomes increases, the absolute differences in time also increase (Fig. 2B). As shown in Figure 2C, the users can customize the parameters of the lightweight JavaScript PWMA module and get instant feedback, which has great potential to enable in-depth exploration of large-scale PWMA results. For example, as shown in Figure 1B, the user can check multiple measures (i.e., odds ratio, risk ratio, and incidence) at the same time and compare the differences between a large number of patient-important outcomes.

Despite the significant performance advantage shown in our prototype, at this stage, the variety of analyses is limited due to the lack of mathematical functionalities in JavaScript. For example, some effect size measurements, such as standardized mean difference, are not implemented at present. As the next steps, we plan to build more meta-analysis tools in JavaScript to support more PWMA of multiple clinical outcomes and conduct user studies to evaluate our visual designs.

REFERENCES

- [1] J. P. Jansen and H. Naci, “Is network meta-analysis as valid as standard pairwise meta-analysis? It all depends on the distribution of effect modifiers,” *BMC Med.*, vol. 11, no. 1, p. 159, Jul. 2013, doi: 10.1186/1741-7015-11-159.
- [2] S. Balduzzi, G. Rücker, and G. Schwarzer, “How to perform a meta-analysis with R: a practical tutorial,” *Evid. Based Ment. Health.* vol. 22, no. 4, pp. 153–160, Nov. 2019, doi: 10.1136/ebmental-2019-300117.
- [3] W. Viechtbauer, “Conducting Meta-Analyses in R with the metafor Package,” *J. Stat. Softw.*, vol. 36, pp. 1–48, Aug. 2010, doi: 10.18637/jss.v036.i03.
- [4] Mathias Harrer, Pim Cuijpers, Toshi Furukawa, and David Daniel Ebert, *dmetar: Companion R Package For The Guide “Doing Meta-Analysis in R.”* 2019. [Online]. Available: <http://dmetar.protectlab.org>
- [5] T. Munzner, “A Nested Model for Visualization Design and Validation,” *IEEE Trans. Vis. Comput. Graph.*, vol. 15, no. 6, pp. 921–928, Nov. 2009, doi: 10.1109/TVCG.2009.111.
- [6] S. Eismann et al., “Serverless Applications: Why, When, and How?,” *IEEE Softw.*, vol. 38, no. 1, pp. 32–39, Jan. 2021, doi: 10.1109/MS.2020.3023302.