Towards Real-time Visual Exploration of Network Meta-analysis Results

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Abstract

Network meta-analysis (NMA) allows the comparative effectiveness of multiple competing interventions, even when they have not been directly compared in clinical trials. However, the presentation of complex NMA results is limited by static and unidimensional tabulations and visualizations that often omit critically important details necessary for clinical decision making. To address this challenge, we propose, with the input of methodologists and clinicians, a web-based interactive visualization technique to help visualize and explore the NMA results in real time.

Introduction and Background

Network meta-analysis (NMA) provides a statistical framework to compare multiple treatment options simultaneously using direct and indirect evidence[1]. Several statistical tools such as WinBUGS, OpenBUGS, NetMetaXL, and numerous R packages (dmetar, netmeta, gemtc, and BUGSnet) are available to conduct these analyses.

A balanced presentation of benefits and harms displayed with relative effects across patient-important outcomes for multiple treatment options is essential for a good quality NMA. However, the presentation of NMA results to clinicians for shared-decision making, policymakers, and guideline developers is limited by static and unidimensional tabulations and visualizations that often omit critically important details necessary for clinical decision making. While it is possible to develop interactive web applications to visualize NMA results, the process requires technical expertise and manual effort. Hence, such solutions are not readily available for practice. Moreover, as the network expands with the evolving evidence, not only does the number of primary studies and outcomes increase but also the time spent on computation and manual configuration increases.

Therefore, to address the aforementioned limitations, we propose a hybrid framework to provide a real-time visual exploration of NMA results to help clinical researchers to understand the NMA results. Our proposed framework, along with the source code of our lightweight NMA module and other scripts with technical details, are available in our GitHub repository for online demonstration (https://ohnlp.github.io/Meta.js/).

Methods

We adopted a hybrid framework to design an interface that accommodates comprehensive statistics associated with a NMA and real-time visual exploration of the results. First, we designed an optional standalone NMA web service module based on existing R-based NMA libraries providing support to conduct in-depth and comprehensive data analysis. Second, we adopted the serverless architecture, which removes the need for a traditional always-on server to host web applications [2], enabling the users to explore the evidence in a web browser without any runtime installation. Our proposed hybrid framework consists of three major components: (1) the visualization module, (2) the in-browser data processing module, and (3) the optional NMA web service module (**Figure 1a**).

(1) *Visualization Module*: The visualization module provides an interactive interface to present the NMA results with user-specific analysis parameters. As shown in **Figure 1b**, we leveraged web-based visualization techniques to generate multiple plots showing the NMA results from different perspectives: (1) a network plot outlining the overall geometrical structure of the network along with the associated treatment comparisons included in the network; (2) a forest plot showing the relative effect estimates of multiple treatment options compared to a specified comparator; (3) a league table showing mixed treatment comparisons with color-encoded relative effect estimates; (4) a rank table showing P-score (or surface under the cumulative ranking curve [SUCRA] – not shown here) to evaluate relative treatment rankings.

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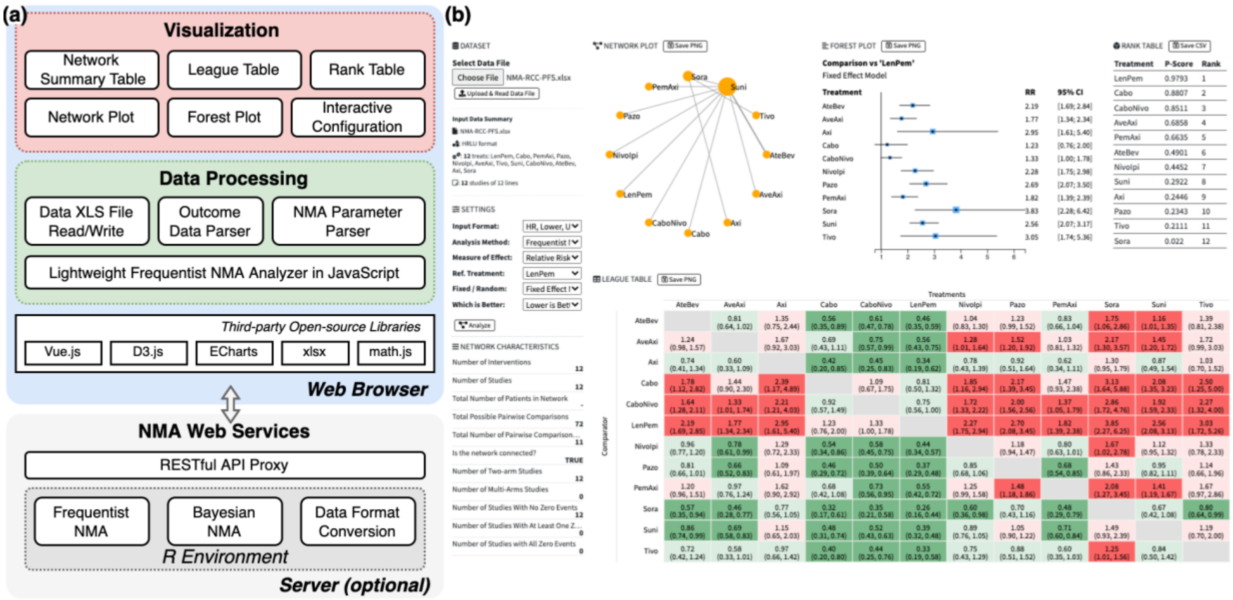

Figure 1. (A) The architecture of our proposed tool which consists of three major components: the visualization module, the in-browser data processing module, and the optional NMA web service module that provides in-depth NMA capabilities. (B) The screenshot of the prototype of our proposed system.

(2) *In-Browser Data Processing Module*: The in-browser data processing module provides the functions required to process the dataset within the user's web browser environment. The user can load a CSV/XLS file with the format defined by the R packages (i.e., meta, netmeta, and BUGSnet) to start meta-analysis. We developed a lightweight frequentist NMA analyzer in JavaScript, which supports basic NMA methods within the Frequentist framework. The analysis is executed in the user's web browser without the installation of runtime environments (e.g., Python and R).

(3) *NMA Web Service Module*: The NMA web service module is an optional feature that is designed to provide two NMA models, frequentist- and Bayesian- NMA, to pool all available network data to conduct in-depth analysis. These NMA models are built on open-source R packages (e.g., meta, netmeta, gemtc, and BUGSnet) and are served through web-based application programming interfaces based on open-source Python packages (e.g., Pandas and Flask). The users can host this module in their own computation environment or any cloud computing platform for in-depth exploration of NMA results.

Discussion and Future Work

The preliminary results suggest that our lightweight frequentist NMA analyzer can achieve significant computation efficiency for fixed effect estimation. Hence, it can be deployed to analyze and visualize complex networks with a large number comparisons and outcomes of interest. Furthermore, it can demonstrate temporal changes in the network, if the evidence is rapidly evolving, a feature particularly relevant to living meta-analyses. For data security, our tool won't send data to any external web server except the user's own NMA web services. The "uploaded" data file is processed within the user's local web browser or NMA web service module.

This demonstration is limited to fixed-effect NMA within the frequentist framework given the narrow mathematical functionalities in JavaScript. A full-range of methods will require developing a infrastructure with many third-party libraries to support linear algebra and statistical functions for various meta-analysis tasks. As the next steps, (1) we plan to improve the usability of the interactive charts which can enable more in-depth exploration of NMA results, (2) provide certainty of evidence for each clinically relevant comparison, including the risk of bias, publication bias, inconsistency, indirectness, imprecision, transitivity, and incoherence, and (3) integrate the NMA results as interactive charts in online publication for creating living guidance.

References

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