

# Introduction

2021-12-07

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Scientific production has experienced continuous exponential growth in the last decades (Bornmann & Mutz, 2015; Larsen & Von Ins, 2010). This is especially true for biomedical research, a trend further increased by the COVID-19 pandemic, thanks to faster article’ processing time by publishers and the diffusion of preprint databases’ usage (Aviv-Reuven & Rosenfeld, 2021; Horbach, 2020; Hoy, 2020). Consequently, it gets harder for researchers and practitioners to stay up-to-date on the latest findings in their field. Secondary research is of paramount relevance in this scenario, providing valuable summaries of the latest research results, but is getting ever more demanding in terms of time and human resources (Allen & Olkin, 1999; Bastian et al., 2010; Borah et al., 2017; A. M. Cohen et al., 2010).

The article collection and screening phases of a systematic review are particularly demanding (Babar & Zhang, 2009). First, relevant published research needs to be collected from scientific databases through appropriately built search queries (retrieval phase); secondly, the acquired scientific citations need to be screened, selecting only those relevant to the topic (appraisal phase) (Bannach-Brown et al., 2019; Higgins et al., 2019; Tsafnat et al., 2014).

The construction of search queries is a complex task (Hammerstrøm et al., 2010; Lefebvre et al., 2011), requiring both domain and some knowledge of the databases’ query languages; the goal is to produce a set of results containing all relevant articles (high sensitivity) while keeping the total number low (high specificity), focusing on the first aspect at the cost of the second (Hammerstrøm et al., 2010). If an integrated search tool is not used, manual work is required to download, store and organise the publication data; this approach is complicated by limits in the number of records that can be downloaded at once and the necessity to harmonise different formats and resolve record duplication (Marshall & Wallace, 2019).

The citation screening phase is usually the more resource-demanding task of a systematic review: even with appropriately built search queries, the returned results easily range in the tens of thousands of which just a small fraction is actually relevant (Lefebvre et al., 2011). It was estimated that labelling 10,000 publications may take as much as 40 weeks of work and that the average clinical systematic review takes 63 weeks to be completed (Allen & Olkin, 1999; Bannach-Brown et al., 2019; Borah et al., 2017). A consequence is that often systematic reviews are already outdated once they are published (E. M. Beller et al., 2013).

The field of Data Science applied to evidence synthesis and acquisition has greatly matured in the last years (E. Beller et al., 2018; Marshall & Wallace, 2019; Tsafnat et al., 2014). Through the application of natural language processing (NLP), it is possible to transform free text into quantitative features, with various levels of abstraction and generalisation (Ananiadou & McNaught, 2006; K. B. Cohen & Hunter, 2008); with machine learning, such text-derived data can be used to map and reproduce human judgment, automating the citation screening (Ikonomakis et al., 2005).

The automation of systematic reviews has been ripe with improvements in the last years (Ananiadou et al., 2009; Jonnalagadda et al., 2015; O’Mara-Eves et al., 2015; Tsafnat et al., 2013), and it is possible to foresee that it is going to become the standard approach in the field (E. Beller et al., 2018), with many solutions already being turned into commercial and free-to-use tools (see Marshall & Wallace, 2019, table 1).

In this manuscript we present an open source, production-ready framework which further contributes to the state-of-the-art in systematic review automation (SRA) and helpers (SRH) tools. We improve the “retrieval phase” by providing a unified framework for the automatic collection and management of scientific literature from multiple online sources. For the citation screening (appraisal) phase, we built an active machine learning-based Miwa et al. (2014) protocol, which exploits a Bayesian framework to efficiently identify potentially relevant documents that require human review while automatically screening-out the

large majority of clearly non-relevant ones; the algorithm then uses human reviews to iteratively increase classification accuracy. Finally, we included a tool to generate new search queries given an already labelled citation data set, in order to identify relevant research possibly missed by human-made queries.

We tested the framework in the retrieval and appraisal phases of an example topic of interest for our group: the evaluation of the mathematical modelling of patient referral networks among hospitals and their impact on the diffusion of healthcare-associated pathogenic microorganisms; the protocol is published in (Sadaghiani et al., 2020).

We give an overview of the framework in the Methods section; in the Result section, we show the framework outputs and performance once applied to the example topic; in the Discussion, we lay out the methodological justification behind the different components and features of the framework.

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