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repro_eval: A Python Interface to Reproducibility Measures of System-oriented IR Experiments

Timo Breuer\(^1\), Nicola Ferro\(^2\), Maria Maistro\(^3\), and Philipp Schaer\(^1\)

\(^1\) TH Köln - University of Applied Sciences, Germany
\{timo.breuer,philipp.schaer\}@th-koeln.de
\(^2\) University of Padua, Italy
ferro@dei.unipd.it
\(^3\) University of Copenhagen, Denmark
mm@di.ku.dk

Abstract. In this work we introduce repro_eval - a tool for reactive reproducibility studies of system-oriented Information Retrieval (IR) experiments. The corresponding Python package provides IR researchers with measures for different levels of reproduction when evaluating their systems' outputs. By offering an easily extensible interface, we hope to stimulate common practices when conducting a reproducibility study of system-oriented IR experiments.

Keywords: Replicability · Reproducibility · Evaluation.

1 Introduction

Reproducibility is a cornerstone of scientific findings. However, many scientific fields are affected by reproducibility issues \(^2\) and IR is not an exception \(^6\). In the previous decade, different communities from the computational sciences developed a range of tools supporting researchers in their attempts to make studies reproducible.

According to Potthast et al. \(^12\) reproducibility efforts can be subdivided into either proactive, reactive or supportive actions. Many existing tools for reproducibility support proactive actions. More general examples include Ro-Hub \(^11\), CodaLab \(^4\) (executable papers), ReproZip \(^4\) (workflow tracking, data provenance), Process Migration Framework (system resource logging) \(^13\), ReproMatch \(^5\) (search engine for reproducibility tools), noWorkflow \(^10\) (monitoring data provenance), yesWorkflow \(^9\) and others. With special regards to system-oriented IR experiments, the implementations and requirements can be proactively packaged with virtual machines or as shown more recently with Docker

\(^4\) https://codalab.org/
\(^5\) http://repromatch.poly.edu/tools/search/
containers as exemplified by TIRA [12] and the OSIRRC platform [5], respectively. On the other hand, the IR community promotes reactive reproducibility studies by archiving experimental data from evaluation campaigns at TREC [15] or CLEF [1]. Here, we can use the artifacts - or more specifically system runs - of previous experiments as points of reference to which we compare the results of our reimplementations. Tools of supportive actions have been realized as Evaluation-as-a-Service infrastructures and shared task platforms [8].

The presented software complements existing reproducibility tools by measuring the exactness of reproduced system runs in relation to their original counterparts. It is often not sufficient to compare system results based on their average retrieval performance (ARP), as the averaged scores may hide differences between the distributions of topic scores or the order of documents. In this sense, repro_eval supports researchers as part of their reactive approach when reimplementing another researcher’s retrieval system. The implemented measures of repro_eval provide the reproducer with insights at different levels of reproduction. Under consideration of these insights, repro_eval contributes to the adequate use of reimplemented systems, for instance when they are used as baseline systems in experimental evaluations.

2 Evaluating Reimplementations with repro_eval

The presented Python package compiles system-oriented reproducibility measures we introduced in previous studies [3]. According to the ACM policy of Artifact Review and Badging\footnote{https://www.acm.org/publications/policies/artifact-review-badging}, we align the system-oriented IR experiment to the terminology it introduces. More specifically, repro_eval can be used to evaluate the reproducibility with a reimplemented IR system in combination with the \textit{same test collection} of the original experiments, whereas replicability considers the reimplemention in combination with a \textit{different test collection}.

In this sense, repro_eval supports IR researchers who want to compare their systems to a reference or state-of-the-art system for which no source code or public artifact is available. Especially, when reference systems need to be evaluated in a different context (with a possibly different test collection), IR researchers cannot rely on the results reported in the original publication. With repro_eval they can evaluate their reimplemented reference system and gain insight into how similar the two systems are. With an increasing level of specificity, the Python package provides different measures that provide a more nuanced perspective on the degree of reproduction and replication. Figure 1 provides a hierarchical illustration of the different levels and corresponding measures.

Proceeding from the bottom to the top of this hierarchy, the specificity of reproduction (and replication) increases from the most general to the most specific. Note that some evaluations are limited to reproduced experiments only. The ordering of documents can only be compared if all systems runs (possibly) contain the same documents or were derived from the same test collection.
Likewise, the level of effectiveness can only be determined if reproduced runs are derived for the same topics as in the original experiment. Here, the Root Mean Square Error (RMSE) evaluates the closeness of the topic scores distributions between the reproduced and original results. In order to evaluate replicated runs, reimplementations need to be compared on more general levels. The overall effects are determined with the help of the Effect Ratio (ER) and the Delta Relative Improvement (DeltaRI). To do so, a replicated baseline run and an improved version of it (which we refer to as the advanced run) are required. The ER and DeltaRI measure how accurately the effects between the baseline and the advanced run can be replicated. At the most general level, it is possible to compare the topic score distributions of the reproduced and replicated runs with paired and unpaired t-tests, respectively. The p-values deliver information about the success of reproduction and replication. In case of a low p-value, there is a strong evidence that the repeated experiment has failed.

3 Case Study on the Evaluation of Reproducibility

Let us consider IR researchers reimplementing a retrieval system of another research group that provides no other artifacts except for the description in the publication and the original run files. Having reimplemented the system, the researchers want to know about the quality of their reproductions/replications. Since the publication lacks some details about optional processing steps or parameterizations, the researchers try different variations and end up having many runs. How do they know which one is the most exactly reproduced/replicated run? Intuitively, they can compare the runs by the ARP. However, equal (averaged) scores might hide differences between the topic score distributions or document orderings. Furthermore, replicated runs (derived from another test collection) cannot be compared at these two levels.

In this case, repro_eval provides a toolbox of different measures for reproducibility and replicability. It is a Python package which uses the Pytrec_eval [7]
Fig. 2: repro_eval as a cornerstone for statistical and visual analytics of reproducibility studies with the help of Colab.

interface to trec_eval\textsuperscript{7} as well as numpy \textsuperscript{10} and scipy \textsuperscript{14}. Once installed, repro_eval can be used either by a conventional command line call (similar to trec_eval) or by importing it into programs as exemplified by the Colab-based tool for visually analysing the reproducibility and replicability (see Figure 2).

We provide an interactive demonstration in a Colab-based environment featuring example data that complies with the previously outlined use case\textsuperscript{8}. Besides numerical outputs comparable to those of trec_eval, our demonstration showcases some plots that help researchers to gain a better understanding of the reproductions. Bar plots visualize conventional comparisons at the level of ARP, whereas the included plots of Kendall’s $\tau$ Union and the RMSE illustrate the reproduction quality across the cut-off ranks. At the level of overall effects, the ER/DeltaRI plots are a valuable tool helping to explore the space of reproduction/replication. In theory, the best reproduction/replication yields (ER 1 / DeltaRI 0). The included scatter plots visualize which runs resemble the originals in terms of P@10, AP, and nDCG the most.

4 Contributions & Conclusions

We introduce repro_eval, a tool for reproducibility studies of system-oriented IR experiments. This tool provides a Python package that can be used by researchers in their reactive approach to reimplement another researchers’ experiments. The included reproducibility and replicability measures offer assistance when measuring the closeness of reimplemented systems’ outputs compared to the original results. More technical details, installation instructions and a demonstration video of repro_eval can be found in our public GitHub repository\textsuperscript{9}.

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References

1. Agosti, M., Nunzio, G.M.D., Ferro, N., Silvello, G.: An innovative approach to data management and curation of experimental data generated through IR test collections. In: Ferro, N., Peters, C. (eds.) Information Retrieval Evaluation in a Changing World - Lessons Learned from 20 Years of CLEF, The Information Retrieval Series, vol. 41, pp. 105–122. Springer (2019). https://doi.org/10.1007/978-3-030-22948-1_4

2. Baker, M.: 1,500 scientists lift the lid on reproducibility. Nature 533, 452–454 (2016)

3. Breuer, T., Ferro, N., Fuhr, N., Maistro, M., Sakai, T., Schaer, P., Soboroff, I.: How to measure the reproducibility of system-oriented IR experiments. In: Huang, J., Chang, Y., Cheng, X., Kamps, J., Murdock, V., Wen, J., Liu, Y. (eds.) Proceedings of the 43rd International ACM SIGIR conference on research and development in Information Retrieval, SIGIR 2020, Virtual Event, China, July 25-30, 2020. pp. 349–358. ACM (2020). https://doi.org/10.1145/3397271.3401036

4. Chirigati, F., Rampin, R., Shasha, D.E., Freire, J.: Reprozip: Computational reproducibility with ease. In: ¨Ozcan, F., Koutrika, G., Madden, S. (eds.) Proceedings of the 2016 International Conference on Management of Data, SIGMOD Conference 2016, San Francisco, CA, USA, June 26 - July 01, 2016. pp. 2085–2088. ACM (2016). https://doi.org/10.1145/2882903.2899401

5. Clancy, R., Ferro, N., Hauff, C., Lin, J., Sakai, T., Wu, Z.Z.: The SIGIR 2019 open-source IR replicability challenge (OSIRRC 2019). In: Piwowarski, B., Chevalier, M., Gaussier, É., Maarek, Y., Nie, J., Scholer, F. (eds.) Proceedings of the 42nd International ACM SIGIR Conference on Research and Development in Information Retrieval, SIGIR 2019, Paris, France, July 21-25, 2019. pp. 1432–1434. ACM (2019). https://doi.org/10.1145/3331184.3331647

6. Ferro, N.: Reproducibility challenges in information retrieval evaluation. J. Data and Information Quality 8(2), 8:1–8:4 (2017). https://doi.org/10.1145/3020206

7. Gysel, C.V., de Rijke, M.: Pytrec_eval: An extremely fast python interface to treec_eval. In: Collins-Thompson, K., Mei, Q., Davison, B.D., Liu, Y., Yilmaz, E. (eds.) The 41st International ACM SIGIR Conference on Research & Development in Information Retrieval, SIGIR 2018, Ann Arbor, MI, USA, July 08-12, 2018. pp. 873–876. ACM (2018). https://doi.org/10.1145/3209978.3210065

8. Hopfgartner, F., Hanbury, A., Müller, H., Eggel, I., Balog, K., Brodt, T., Cormack, G.V., Lin, J., Kalpathy-Cramer, J., Kando, N., Kato, M.P., Krithara, A., Gollub, T., Potthast, M., Viegas, E., Mercer, S.: Evaluation-as-a-service for the computational sciences: Overview and outlook. ACM J. Data Inf. Qual. 10(4), 15:1–15:32 (2018). https://doi.org/10.1145/3239570

9. McPhillips, T.M., Song, T., Kolisnik, T., Aulenbach, S., Belhajjame, K., Bocinsky, K., Cao, Y., Chirigati, F., Dey, S.C., Freire, J., Huntzinger, D.N., Jones, C., Koop, D., Missier, P., Schildhauer, M., Schwallm, C.R., Wei, Y., Cheney, J., Bieda, M., Lüdäsch, B.: Yesworkflow: A user-oriented, language-independent tool for recovering workflow information from scripts. CoRR abs/1502.02403 (2015), http://arxiv.org/abs/1502.02403
10. Murta, L., Braganholo, V., Chirigati, F., Koop, D., Freire, J.: noworkflow: Capturing and analyzing provenance of scripts. In: Ludäscher, B., Plale, B. (eds.) Provenance and Annotation of Data and Processes - 5th International Provenance and Annotation Workshop, IPAW 2014, Cologne, Germany, June 9-13, 2014. Revised Selected Papers. Lecture Notes in Computer Science, vol. 8628, pp. 71–83. Springer (2014). https://doi.org/10.1007/978-3-319-16462-5_6

11. Palma, R., Holubowicz, P., Corcho, Ó., Gómez-Pérez, J.M., Mazurek, C.: Rohub - A digital library of research objects supporting scientists towards reproducible science. In: Presutti, V., Stankovic, M., Cambria, E., Cantador, I., Iorio, A.D., Noia, T.D., Lange, C., Recupero, D.R., Tordai, A. (eds.) Semantic Web Evaluation Challenge - SemWebEval 2014 at ESWC 2014, Anissaras, Crete, Greece, May 25-29, 2014, Revised Selected Papers. Communications in Computer and Information Science, vol. 475, pp. 77–82. Springer (2014). https://doi.org/10.1007/978-3-319-12024-9_9

12. Potthast, M., Gollub, T., Wiegmann, M., Stein, B.: TIRA integrated research architecture. In: Ferro, N., Peters, C. (eds.) Information Retrieval Evaluation in a Changing World - Lessons Learned from 20 Years of CLEF, The Information Retrieval Series, vol. 41, pp. 123–160. Springer (2019). https://doi.org/10.1007/978-3-030-22948-1_5

13. Rauber, A., Miksa, T., Mayer, R., Pröll, S.: Repeatability and re-usability in scientific processes: Process context, data identification and verification. In: Kalinichenko, L.A., Starkov, S. (eds.) Selected Papers of the XVII International Conference on Data Analytics and Management in Data Intensive Domains (DAMID/RCDL 2015), Obninsk, Russia, October 13-16, 2015. CEUR Workshop Proceedings, vol. 1536, pp. 246–256. CEUR-WS.org (2015). http://ceur-ws.org/Vol-1536/paper33.pdf

14. Virtanen, P., Gommers, R., Oliphant, T.E., Haberland, M., Reddy, T., Cournapeau, D., Burovski, E., Peterson, P., Weckesser, W., Bright, J., van der Walt, S., Brett, M., Wilson, J., Millman, K.J., Mayorov, N., Nelson, A.R.J., Jones, E., Kern, R., Larson, E., Carey, C.J., Polat, I., Feng, Y., Moore, E.W., VanderPlas, J., Laxalde, D., Perktold, J., Cimrman, R., Henriksen, I., Quintero, E.A., Harris, C.R., Archibald, A.M., Ribeiro, A.H., Pedregosa, F., van Mulbregt, P., SciPy: Scipy 1.0-fundamental algorithms for scientific computing in python. CoRR abs/1907.10121 (2019). http://arxiv.org/abs/1907.10121

15. Voorhees, E.M., Rajput, S., Soboroff, I.: Promoting repeatability through open runs. In: Yilmaz, E., Clarke, C.L.A. (eds.) Proceedings of the Seventh International Workshop on Evaluating Information Access, EVIA 2016, a Satellite Workshop of the NTCIR-12 Conference, National Center of Sciences, Tokyo, Japan, June 7, 2016. National Institute of Informatics (NII) (2016). http://research.nii.ac.jp/ntcir/workshop/OnlineProceedings12/pdf/evia/04-EVIA2016-VoorheesE.pdf

16. van der Walt, S., Colbert, S.C., Varoquaux, G.: The numpy array: A structure for efficient numerical computation. Comput. Sci. Eng. 13(2), 22–30 (2011). https://doi.org/10.1109/MCSE.2011.37