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Offline Evaluation for Information Retrieval

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Abstract

Offline evaluation provides characterization of an information retrieval (IR) system based on human judgments without relying on actual users in real-world environment. Offline evaluation, notably test collection based evaluation, has been dominant approaches in IR evaluation. It is no exaggeration that shared evaluation efforts such as TREC has defined the IR research over the years. The reason for this success lies in the ability to compare retrieval systems in a reusable manner.

Recently, there has been several trends which necessitates the change in the role and method of offline evaluation. First and foremost, online search engines with large-scale user base has become commonplace, enabling online evaluation based on user behavior. Also, there are many endpoints for search beyond desktop web browser such as mobile phone and conversational agents, and the types of search results has diversified beyond the list of web documents to include other results types and direct answers. Finally, crowdsourcing has provided ways for human judgments of any kind to be collected at an large scale. The overall outcome of this trend is the advent of new IR evaluation paradigms which are more user-centric, diverse and agile.

This survey aims to provide an overview of recent research in IR evaluation pertaining to the trends above. We first introduce offline evaluation for IR, focusing on how it relates to other evaluation paradigms such as online evaluation. We also overview traditional offline evaluation for IR, and how recent trends have shaped the research so far. We then review research in offline evaluation mainly on three levels: human judgment, evaluation metric and experiment design. This organization will allow readers to follow recent developments in research from micro-level (human judgment) to macro-level (experiment). Finally, we discuss evaluation practices from industry, which has been a major driving force in research and development in IR.

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1

Introduction

In this chapter, we survey the area and lay conceptual foundation for the rest of the paper. We first provide an overview of different approaches to IR evaluation. We then focus on general overview of offline evaluation, explaining traditional approaches and recent trends. Finally, we introduce a conceptual framework and the outline for the rest of this paper. (15-20 pages)

1.1 Evaluation Paradigms in IR

New Landscape in IR Evaluation Research
- User-centric view (understanding user)
- Online evaluation (industry)
- User studies
- More endpoints / models
- Agile experimentation (crowdsourcing)

Online evaluation Katja Hofmann [2016] vs. Offline evaluation Sanderson [2010]
- What is it? Why is it important? How is it used?

- How are they different?

Offline evaluation vs. Counterfactual online evaluation Chuklin et al. [2015] Li et al. [2015, 2010]
- Label-based vs. Behavior-based
- Data from controlled experiments vs. Natural observations

Offline evaluation vs. User study Kelly [2009]
- Focus: system-to-system evaluation vs. understanding interaction/user behavior
- Difference in scale and richness
- Blurred distinction recently Bron et al. [2013] Liu et al. [2014] Shah and González-Ibáñez [2011]

The role of offline evaluation
- Evaluation at the early stage of development
- Experimental control and resolution
- Reusability across experiments

1.2 Offline Evaluation for IR

1.2.1 Traditional Approaches in Offline Evaluation

Conceptual Model
- Labels/Metrics based on Query-URLs
- Test collections
- Concept of relevance

History
- TREC and related evaluation venues Sanderson [2010]

Borlund [2003] Cleverdon [1967] Voorhees and Harman [2005]

1.2.2 Recent Trends in Offline Evaluation

Need for User-centric Evaluation
- Definition: Aiming for user satisfaction, or other user-visible measure such as engagement or task completion (Scholer et al. [2013b]) / Evaluation based on models of user behavior

- Traditional metrics seem to not agree much with user behavior/satisfaction Al-Maskari et al. [2007]

- Cross-metric studies btw. online and offline evaluation Radlinski and Craswell [2010]

Need methodologies to better estimate user satisfaction and behavior

- Metric design Yilmaz et al. [2010], Carterette et al. [2011], Chapelle et al. [2009]

- Judgment design Verma and Yilmaz [2016b], Verma et al. [2016b]

Extending the realms of evaluation

- Whole-page evaluation Zhou et al. [2012]

- Session-level evaluation Kanoulas et al. [2011a], Carterette et al. [2014]

- Desktop vs. Mobile / Typed vs. Spoken IR Verma et al. [2016b]

Online-Offline Hybrid approaches

- Log-based offline evaluation Li et al. [2015] Li et al. [2010]
- Collecting feedback directly from users Kim et al. [2016]
- Crowdsourcing / Agile Experiment

1.3 General Framework for Offline Evaluation

General Components of Offline Evaluation

- Experiment
- Search Task (Query / context)
- Evaluation Metric
- Judging Method (Interface / rating scale)

Organization of this paper: A pipeline for offline evaluation

- Select an audience (who you want to talk to: end users, accountants, sysadmins, advertisers).

- Collect appropriate data: documents, tasks, queries, judgments. Much of this data may already exist; but Chapter 2 deals with gathering judgments, which need to be created for the purpose.

- Choose a metric based on your tasks and on likely user models. Aggregate judgments, if needed, to compute the metric. Chapter 3 considers this.

- Examine the metric to draw some conclusion. This is covered in Chapter 4.

2

Collecting Human Judgments

The first step in offline evaluation is collecting human judgments. In this chapter, we describe various considerations in collecting high-quality labels from human judges at scale. We first discuss the method for collecting search tasks, followed by the design of a judging method. We then discuss the collection of judgments, which is an non-trivial task to perform at scale. (20-25 pages)

2.1 Collecting Search Tasks

Collect hypothetical search tasks

- Examples from user study papers

Sample search tasks from existing system

- Which sampling methods to use? Baeza-Yates [2015]

2.2 Designing a Judging Method

Judging Unit: URL vs. SERP-level evaluation

- Preference Judgment Chandar and Carterette [2013] Carterette et al. [2008]

- Side by side Thomas and Hawking [2006] Kim et al. [2013]
- SASI Bailey et al. [2010]

Judgment for Desktop vs. Mobile environment Verma and Yilmaz [2016a]

Judgment based on Query vs. Intent Description Yilmaz et al. [2014a]

Session/Task-based evaluation Moraveji et al. [2011] Xu and Mease [2009]

Effort based judgments Yilmaz et al. [2014b] Verma et al. [2016a]
- Relevance vs. Usefulness-based evaluation

2.3 Collecting Judgments

Choosing Judges:
- Crowd vs. Expert Kazai et al. [2013] Alonso and Mizzaro [2012]
- Query owner vs. non-owners Chouldechova and Mease [2013]

Reducing noise in judging:
- Anchoring bias in judging Shokouhi et al. [2015]
- Multiple judgments and majority voting, etc. Venanzi et al. [2014] Aroyo and Welty [2013b] Aroyo and Welty [2013a]

Efficient judgment collection using Crowdsourcing
- Design decisions that need to be tackled Blanco et al. [2011] Kazai et al. [2012] Alonso [2012] Alonso et al. [2015] Scholer et al. [2013a]
- Incentivising judges and how to make it more attractive (payment / I/F) Megorskaya et al. [2015] Davtyan et al. [2015] Rokicki et al. [2014] Eickhoff et al. [2012]

2.4 Open Issues

- Collecting labels for contextual / personalized search results
- Collecting labels for whole SERP / non-document results
- Collecting labels for non-traditional endpoints (i.e., conversational agent)

3

Designing Evaluation Metrics

The second step in offline evaluation is designing a meaningful evaluation metric. This is essentially the question of how to combine labels to meaningful numbers. For traditional IR evaluation where the labels are collected at query-URL level, combining labels to a metric requires quite a few assumptions, or even a user model. In this chapter, we go over the various considerations of IR metric design, as well as the user models behind these metrics. (20-25 pages)

3.1 Basic IR evaluation metrics

- Metrics based on absolute judgments (e.g. Cooper [1973])

- Metrics based on preference-based judgments, including e.g. aggregated in-situ side-by-side Thomas and Hawking [2006]

- Ranking-based metrics (Tau/TauAP)

3.2 Metrics based on simple aggregation of labels/qrels

- P, R, AP, RR

3.3 Models of behavior

Evaluation metrics that are based on explicit models of user behavior

- The cascade model and variants
- ERR, EBU, GAP, Time-biased gain, etc.
- Weighted precision metrics such as RBP, INST; notion of residual
- Alpha-NDCG, IA metrics, etc.
- Cost-based/economic models and the prospects of metrics from these
- Session-level metrics Kanoulas et al. [2011b] Järvelin et al. [2008]

3.4 Model fitting

Fit of metrics to models; estimating the distribution of parameters/metric values based on user data

Carterette et al. [2011], Moffat et al. [2013]

3.5 Open issues

Open issues in behavior models and the corresponding metrics

- Whole-page quality
- Caption effects
- Variation between users: behaviors, learning styles, cognitive styles, topic expertise, search system expertise, expectations of the system, query variation, ...
- Duplication in SERPs
- Learning (?)
- Non-traditional tasks

4

Designing and Analyzing Experiments

Experiments is defined as a set of labels and metrics defined on top of them. We first look over many considerations in order to design an experiment given a budget and time constraint. We then focus on a set of analyses we can perform once the data is collected.

4.1 Designing an Experiment

- How to select queries?
    - How many queries? Sakai [2014]
    - How many documents? Carterette et al. [2009a]
    - How to distribute judgment effort across queries and documents? Carterette et al. [2009b], Yilmaz and Robertson [2009]

4.2 Analysis of Experimental Results

Drawing conclusions from metrics ($\approx$ 15 pages)
    - Hypothesis Testing Dinçer et al. [2014]
    - Comparison of different types of significance tests Smucker et al. [2009]

Various analysis - Power analysis Sakai [2014]
- Failure analysis
- Sensitivity and Reliability analysis Urbano et al. [2013]
- Informativeness (MaxEnt) Aslam et al. [2005]
- ETC Bron et al. [2013] Boytsov et al. [2013] Robertson and Kanoulas [2012]

Reporting results
- Effect sizes and distributions, vs point estimates and p values

4.3 Open Issues

5

IR Evaluation in Practice

In this chapter, we review evaluation practices happening in both academia and industry.

5.1 Evaluation Practices from Academia

- Dataset generation efforts (Living labs)

Evaluation in related domains
- Aggregate search Zhou et al. [2013]
- Recommendation systems Gunawardana and Shani [2015]

5.2 Evaluation Practices from Industry

How are the practitioners doing? (≈15 pages)
- Google [1] [2]
- Bing [3]

[1] How Search Works (Google) https://www.google.com/insidesearch/howsearchworks/thestory/

[2] Updating Our Search Quality Rating Guidelines https://webmasters.googleblog.com/2015/11/updating-our-search-quality-rating.html

[3] The Role of Content Quality in Bing Ranking (Bing) http://bit.ly/1T1BaYN

- Netflix Gomez-Uribe and Hunt [2015] [4]
- Facebook [5]

Common features

- Combine online and offline evaluation
- Offline evaluation for early iteration
- Online evaluation for final ship decision

[4]The Netflix Tech Blog: Learning a Personalized Homepage http://techblog.netflix.com/2015/04/learning-personalized-homepage.html

[5]Who Controls Your Facebook Feed (Slate) http://slate.me/1T1BbvU

6

Conclusions

Emerging trends in the tech ecosystem

Future of Offline Evaluation

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