P

Processing Structural Constraints

Andrew Trotman
University of Otago, Dunedin, New Zealand

Definition

When searching unstructured plain text, the user is limited in the expressive power of their query – they can only ask for documents that are about something. When structure is present in the document, and with a query language that supports its use, the user is able to write far more precise queries. For example, searching for "smith" in a document is not necessarily equivalent to searching for "smith" as an author of a document. This increase in expressive power should lead to an increase in precision with no loss in recall. By specifying that "smith" should be the author, all those instances where "smith" was the profession will be dropped (increasing precision), while all those in which "smith" is the author will still be found (maintaining recall).

Historical Background

With the proliferation of structured and semi-structured markup languages such as SGML and XML came the possibility of unifying database and information retrieval technologies. The Evaluation of XML Retrieval (INEX) was founded in 2002 to examine the use of semi-structured data for both technologies. It was expected that the use of structure would not only unify the two technologies but would also improve the performance of both.

Foundations

User Querying Behavior

When using an information retrieval search engine, the user typically has some information need. This information need is expressed by the user as a keyword query. There are many different queries that could be drawn from the same information need. Some might contain only keywords, others phrases, and others a combination of the two. It is the task of the search engine to satisfy the information need given the query. Because the task is not to satisfy the query, the terms in the query can be considered nothing more than hints by the user on how to identify relevant documents. It is likely that some relevant documents will not contain the user's keywords, while others that do might not be relevant.

If the user does not immediately find an answer, they will often change their query, perhaps by adding different keywords or by removing keywords. If the query syntax permits, they might add emphasis markers (plus and minus) to some terms.

With a few exceptions, semi-structured search engines remain experimental, so user behavior cannot be studied in a natural environment.

L. Liu, M.T. Özsu (eds.), *Encyclopedia of Database Systems*,
DOI 10.1007/978-1-4899-7993-3_280-2

Instead the user behavior is expected to mirror that of other search engines or search engines that include some structural restriction.

The model used at INEX is that a user will give a query containing only search terms; then, if they are dissatisfied with the results, they might add structural constraints to their query. The keyword searches are known as content only (CO) and when structure is added as content-only + structure (CO + S) or content-and-structure (CAS) queries. Just as the keywords are hints, so too are the structural constraints. For this reason they are commonly referred to as structural hints.

The addition of structure to an otherwise content-only search leads to a direct comparison of the performance of a search engine before and after the structural constraint has been added. The two queries are instantiations of the same information need, so the same documents or document components are relevant to each query making a direct comparison meaningful.

The analysis of runs submitted to INEX 2005 (against the IEEE document collection) showed no statistical difference in performance between the top CO and top CO + S runs – having structural hints in the query did not improve performance [1]. Even at low levels of recall (1 and 10%), no significant improvement was seen. About half the systems showed a performance gain and the other half no gain.

There are several reasons why improvements are not seen: first it could be a consequence of the structure present in the IEEE collection; second (and more likely) it could be that users are not proficient at providing structural hints.

The result was backed up by a user study [2] in which users were presented with three ways of querying the document collection: keywords, natural language (including structure), and bricks [3] (a graphical user interface). Sixteen users each performed six simulated work tasks, two with each interface. The same conclusion is drawn, that is, no significant improvement was seen when structure was used in querying.

INEX subsequently reexamined this problem, first using the Wikipedia, and then in 2010 the Data Centric Track [4] examined queries over IMDb (people and movies). No improvements were seen when structure was used on the Wikipedia [5]. It was not until the second evaluation over the IMDb (in 2011) that evidence started to emerge that structure may help early precision, but may negatively impact recall [6, 7]. INEX has not run this kind of experiment since 2011.

Structural Constraints

There are two reasons a user might add structural constraints to a query. The first is to constrain the size of the result. When searching a collection of textbooks, it is, perhaps, of little practical use to identify a book that satisfies the user need. A better result might be a chapter from the book, or a section from the chapter, or even a single paragraph. One way to identify the best granularity of result is to allow the user to specify this as part of the query. These elements are known as target elements.

The user may also wish to narrow the search to just those parts of a document he or she knows to be appropriate. In this case the user might search for "smith" as an author in order to disambiguate the use from that as any of: an author, a profession, a street, or a food manufacturer. Restricting a query to a given element does not affect the granularity of the result; instead it lends support on where to look so such elements are known as support elements. Both target elements and support elements can appear in the same query.

It is not at all obvious from a query whether or not the user expects the constraint to be interpreted precisely (strictly) or imprecisely (vaguely). In the case of "smith" as an author, it is likely that "smith" as a profession is inappropriate, but "smith" as an editor might be appropriate. If the target element is a paragraph, then a document abstract (about the size of a paragraph) is likely to be appropriate, but a book not so.

The four possible interpretations of a query were examined at INEX 2005 [8]. Runs that perform well with one interpretation of the target elements do so regardless of the interpretation of the support elements. The interpretation of the target element does, however, matter. The consequence is that the search engine needs to know, as part of the query, whether a strict or vague interpretation of the target element is expected by the user.

Processing Structural Constraints

Given a search engine, the strict interpretation of target elements can be satisfied by a simple post-process eliminating all results that do not match. As just discussed above, strictly processing support elements has been shown to be unnecessary.

Several techniques for vaguely satisfying target element constraints have been examined including ignoring them, pre-generating a set of tag equivalences, boosting the score of elements that match the target element, and propagating scores up the document tree.

Ignoring Structural Constraints

Structural constraints might be removed from the query altogether and a content-only search engine used to identify the correct granularity of result.

Tag Equivalence

A straightforward method for vaguely processing structural constraints is tag equivalence. A set of informational groups are chosen a priori, and all tags in the DTD (DTD is the document type definition, specifying the format of the XML documents forming the collection) are mapped to these groups. If, for example, <p> is used for paragraphs and <ip> is used for initial paragraphs, these would be grouped into a single paragraph group.

Mass and Mandelbrod [9] a priori choose appropriate retrieval units (target elements) for the document collection and build a separate index for each. The decision about which units these are is made by a human before indexing. A separate index is built for each unit, and the search is run in parallel on each index. Within each index the traditional vector space model is used for ranking. The lexicon of their inverted index contains term and context (path) information making strict evaluation possible. Vague evaluation of paths is done by matching lexicon term contexts against a tag equivalence list.

Mihajlović et al. [10] build their tag equivalence lists using two methods, both based on prior knowledge of relevance. For INEX 2005 they build the first list by taking the results from INEX 2004 and selecting the most frequent highly and fairly relevant elements and adding the most frequently seen elements from the queries. In the second method, they take the relevant elements from previous queries targeting the same element and normalize a weight by the frequency of the element in the previous result set (the training data, in this case INEX 2004). Using this second method, they automatically construct many different tag equivalence sets using the different levels of relevance seen in the training data.

In a heterogeneous environment in which many different tags from many different DTDs are semantically but not syntactically identical, techniques from research into schema matching [11] might be used to automatically identify tag equivalence lists.

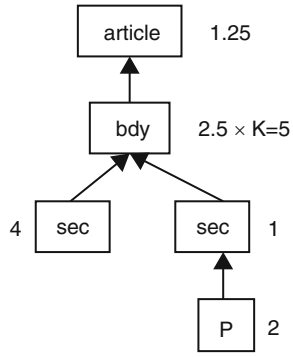
Structure Boosting

Van Zwol [12] generates a set of results ignoring structural constraints and then boosts the score of those that do match the constraints by linearly scaling by some tag-specific constant. The consequence is to boost the score of elements that match the structural constraints while not removing those that do not. A score penalty is also used for deep and frequent tags in the expectation of lowering the score of highly frequent (and short) tags. A similar technique is used by Theobald et al. [13] who use it with score propagation.

Score Propagation

Scores for elements at the leaves of the document tree (i.e., the text) are computed from their content. Scores for nodes internal to the document tree are computed from the leaves by propagating scores up the tree until finally a score for the root is computed. Typically as the score propagates further up the tree, its contribution to the score of an ancestor node is reduced (see the entry on "Propagation Based Structured Text Retrieval" and for details).

Figure 1 illustrates score propagation. A search term is found to occur two times in the p element and four times in the (left) sec element. With a decay factor of 0.5, the score of the bdy element is computed as 4 *0.5 + 2 * 0.5 * 0.5 = 2.5. The score for the article element is computed from that score likewise. If the target



Processing Structural Constraints, Fig. 1 Score propagation, each time a score is propagated, the score is weakened (in the example: halved), but at target nodes it is boosted (in the example: K = 2)

element is bdy and the score, for example, is boosted by $K = 5$, then the element with the highest score is that element. The score for K and the propagation value are chosen here for illustrative purposes only and should be computed appropriately for a given document collection.

Hurbert [14] uses score propagation with structure reduction – if a node in the tree does not match a constraint in the query, then the score there is reduced by some factor. In this way all nodes in the tree obtain scores, but those matching the constraints are over-selected for. Sauvagnat et al. [15] use score propagation in a similar way but in combination with tag equivalence.

Key Applications

Retrieval of document components from structured document collections.

Future Directions

The best performing search engines that interpret structural constraints were shown at INEX 2011 to outperform those that ignore them; however this result is shown on only one document collection, with a relatively small number of topics and a small number of participants – it should be considered preliminary. Several reasons have been suggested for the long string of negative results.

There is evidence to suggest specifying a structural constraint is difficult for a user. Studies into the use of structure in INEX queries suggest that even expert users, when asked to give structured queries, give simple queries [1]. This is in line with studies that show virtually no use of advanced search facilities on the web.

Structure-aware search engines are not as mature as web search engines, and as yet the best way to use structural constraints (when present in a query) is unknown. The annual INEX workshop provides a forum for testing and presenting new methods.

Improvements were not seen when the IEEE document collection or Wikipedia was used, but were seen when IMDb was used. At the very least, this suggests that the result is collection specific. Alternative collections including newspapers, radio broadcast, and television have been suggested [16, 17]. It is not known that characteristic of a document collection indicates that a structured approach will be effective.

Relevance feedback including structural constraints has been examined. Users might provide feedback on both the desired content and the preferred target element or just one of these. Evidence suggests that including structure in relevance feedback does improve precision.

Experimental Results

Evidence that the use of structure increases precision is tentative. In the XML search engine of Kamps et al. [18], no significant difference is seen overall; however significant differences are seen at early recall points (the first few tens of documents). Wang et al. [7] observe an early precision increases but loss in recall. The search engine of Geva [19] performs better without structure than with. That of Trotman [20], often used to generate baselines at INEX, also performs well by ignoring structure.

At INEX 2005, a comparative analysis of performance with and without structural constraints

on the same set of information needs was performed [5]. The best structure run was compared to the best non-structure run, and no significant difference was found. Not even a significant difference at early recall points was found. On a system-by-system basis, about half the search engines show a performance increase. However, at INEX 2011, and using the IMDb collection, the top runs used structural hints, and analysis suggests that structure does help early precision but negatively affects recall.

Cross-References

- Content-and-Structure Query
- Content-Only Query
- INitiative for the Evaluation of XML Retrieval
- Mean Average Precision
- Narrowed Extended XPath 1
- Propagation-based Structured Text Retrieval
- XML Retrieval

Recommended Reading

1. Trotman A, Lalmas M. Why structural hints in queries do not help XML retrieval. In: Proceedings of 32nd annual international ACM SIGIR conference on research and development in information retrieval; Seattle, Washington; 2006. p. 711–2.
2. Woodley A, Geva S, Edwards SL. Comparing XML-IR query formation interfaces. Aust J Intell Inf Proc Syst. 2007;9(2):64–71.
3. van Zwol R, Baas J, van Oostendorp H, Wiering F. Bricks: the building blocks to tackle query formulation in structured document retrieval. In: Proceedings of 28th European conference on IR research; London, UK; 2006. p. 314–25.
4. Trotman A, Wang Q. Overview of the INEX 2010 data centric track. In: Proceedings of 9th international workshop of the initiative for the evaluation of XML retrieval; Vugh, The Netherlands; 2010. p. 171–81.
5. Arvola P, Geva S, Kamps J, Schenkel R, Trotman A, Vainio J. Overview of the INEX 2010 ad hoc track. In: Proceedings of 9th international workshop of the initiative for the evaluation of XML retrieval; Vugh, The Netherlands; 2010. p. 1–32.
6. Schuth A, Marx M. University of Amsterdam data centric ad hoc and faceted search runs. In: Proceedings of 10th international workshop of the initiative for the evaluation of XML retrieval; Saarbrücken, Germany; 2011. p. 155–60.
7. Wang Q, Gan Y, Sun Y. RUC @ INEX 2011 data-centric track. In: Proceedings of 10th international workshop of the initiative for the evaluation of XML retrieval; Saarbrücken, Germany; 2011. p. 167–79.
8. Trotman A, Lalmas M. Strict and vague interpretation of XML-retrieval queries. In: Proceedings of 32nd annual international ACM SIGIR conference on research and development in information retrieval; Seattle, Washington; 2006. p. 709–10.
9. Mass Y, Mandelbrod M. Using the INEX environment as a test bed for various user models for XML retrieval. In: Proceedings of 4th international workshop of the initiative for the evaluation of XML retrieval. Dagstuhl, Germany; 2006. p 187–95.
10. Mihajlovic V, Ramírez G, Westerveld T, Hiemstra D, Blok HE, de Vries AP. Vtijah scratches INEX 2005: vague element selection, image search, overlap, and relevance feedback. In: Proceedings of 4th international workshop of the initiative for the evaluation of XML retrieval; Dagstuhl, Germany; 2006. p. 72–87.
11. Doan A, Halevy AY. Semantic integration research in the database community: a brief survey. AI Mag. 2005;26(1):83–94.
12. van Zwol R. B^3-sdr and effective use of structural hints. In: Proceedings of 4th international workshop of the initiative for the evaluation of XML retrieval. Dagstuhl, Germany; 2005. p. 146–60.
13. Theobald M., Schenkel R., and Weikum G. Topx and xxl at INEX 2005. In: Proceedings of 4th international workshop of the initiative for the evaluation of XML retrieval; Dagstuhl, Germany; 2006. p. 282–95.
14. Hubert G. XML retrieval based on direct contribution of query components. In: Proceedings of 4th international workshop of the initiative for the evaluation of XML retrieval; Dagstuhl, Germany; 2006. p. 172–86.
15. Sauvagnat K, Hlaoua L, Boughanem M. Xfirm at INEX 2005: ad-hoc and relevance feedback tracks. In: Proceedings of 4th international workshop of the initiative for the evaluation of XML retrieval; Dagstuhl, Germany; 2006. p. 88–103.
16. O'Keefe RA If INEX is the answer, what is the question? In: Proceedings of 3rd international workshop of the initiative for the evaluation of XML retrieval; Dagstuhl, Germany; 2005. p. 54–9.
17. Trotman A. Wanted: element retrieval users. In: Proceedings of INEX 2005 workshop on element retrieval methodology; Dagstuhl, Germany; 2005. p. 63–9.
18. Kamps J, Marx M, Rijke MD, Sigurbjörnsson B. Articulating information needs in XML query languages. Trans Inf Sys. 2006;24(4):407–36.
19. Geva S. GPX – gardens point XML IR at INEX 2006. In: Proceedings of 5th international workshop of the initiative for the evaluation of xml retrieval; Dagstuhl, Germany; 2007. p. 137–50.
20. Trotman A, Jia X-F, Crane M. Towards an efficient and effective search engine. In: Proceedings of SIGIR 2012 workshop on open source information retrieval; Portland, Oregon; 2012. p. 40–7.