Infer XPath
Application – Work in progress report

Michał J. Gajda¹, Hai Nguyen Quang², Do Ngoc Khanh², and Vuong Hai Thanh²

¹ Migamake Pte Ltd
migamake@migamake.com

² Kikai Tech
migamake@migamake.com

1 Introduction

Semistructured data⁹ schematisation⁸ has a long history of research and is one of the most practical AI challenges⁷, ¹⁰.

Nowadays, with most data available on the web, it got a new name of “scrapping” and with it much tarnished reputation⁴.

We look at the problem as a discovery of the answer sets desired by the user. Coming from XPath selectors² background we propose a way to construct selectors automatically, and discover schemas of the semistructured data by a combination of lazy path reconstruction, and lazy preference functions.

2 Overview

We first offer to expand declarative language XPath² that was originally invented for generic XML documents into XPath BE (Browser Extensions) with additional operators that facilitate navigation consistent with the visual and logical structure of the web page. We propose new axes that explicitly navigate the tables and visual relations between different page elements.

We also propose how to facilitate understanding of entire websites, by providing XPath function that allows for lazy navigation over the whole website, instead of just a single page.

As a second step, we to propose a way to recognise semantic elements on the web page automatically by extended regular expression matching on the text content entire subtrees, instead of nodes as it is done in plain XPath. This allows us for fast classification of sets of semantic values³ within the document(s).

Our next step is to propose a meta-language InferXPath that takes sets of semantic values and finds possible queries that connect these sets. Since there

³ By semantic value set we indicate a set of recognisable entities of the same type that can be extracted as text content of any subtree within the document(s).
are many possible queries, but we are only interested in the simplest query that satisfies our conditions, we can compute them lazily.
That should give us a set of tables that provide a structured view of the data for systematic data analysis.

Fig. 1: Overview of the InferXPath system

3 XPath browser extensions

3.1 Introduction to XPath
XPath is a query language proposed for the XML documents, and quite popular for selecting fragments of HTML DOM object model of the web page. It is a sequence of selections joined by / sequencing operator, or | alternative operator. Each selection is either a single step across the axis, a function call, or a predicate. Axis step child::* refers to all the child elements, or root::* which moves to a single root element within the document. Each axis step may additionally have a condition on the name of the node selected: child::*h1 will only select h1 element node that is a direct descendant of any node within the current query set.
Predicates are written as [..subquery..] select a set of nodes that answer the subquery with a truthy value. Function calls take a number of arguments that each contains a node-set described by a subquery, for example concat(a/text()).
Beside core XPath, there are several syntactic sugar shorthands for the core XPath expressions.

It has been frequently proposed to describe XPath selection expressions by non-deterministic tree automata accepting nodes within the selected node-set. It bears no relation to our work since we can also precompute containment and subtree relations as a part of a document database.

\[
\text{//table/(td|th)}
\]

Fig. 2: Example XPath expression ‘//table/td—th’ rendered as a graph.

\[
\text{link(//a/@href)}
\]

Fig. 3: Example XPath expression ‘link(//a/@href)’ rendered as a graph.

\[
\text{//div[@class='article']//table[@class='parameters']/td}
\]

Fig. 4: Example XPath expression ‘//div[@class='article']//table[@class='parameters']/td’ rendered as a graph.

In our system we only need to consider the XPath axes that correspond to simplest structural relations:

- \text{child::*},
3.2 XPath BE

Here we describe Browser Extensions to XPath language[???] that allow navigation consistent with visual rendering and logical structure of the web page, beside classical axes that navigate along the tree structure of the DOM[4] document.

Table selectors We also introduce new, semantic selectors to XPath in order to facilitate high-level analysis of tables:

- within a table, we add row::* selector that selects all `<td>`'s within a single table row (technically same as../td for within a `td`, and td from `tr` node)
- column::* means all the entries in the same table column as a given `th` or `td` element. For example, to find all `td` elements within the same column, as `th` element with a text node containing exact String "Address", we write: `/table/thead/th[text()="Address"]/column::td``

Visual relations We can use WebDriver interface[13] to find the bounding box of each node in HTML DOM, and thus allow querying visual relations between tree nodes.

We propose to translate all visual axes into range queries in order to implement the new visual axes:

- contained-in::* – whether DOM node is encompassed within another node
- overlaps::* – whether a DOM node is visually overlapping with another node
- right::* , left::* , up::* , down::* – whether DOM nodes bounding box is strictly in the given direction on the web page

Additionally, we propose to query for current font name and family used to visualise text within the node in order to pick the visual cues:

- font-family()
- font-style()

Image tagging Given the rise of automatic image processing, we also want to match on the tags assigned to images by AI algorithms[5, 6, 11, 12]. We propose the syntax:

- imagenet($nn, .//img) for all tags inferred for each image,
- and imagenet($nn, .//img, "bottle") for just checking if an image contains the bottle.

Here $nn variable should be defined by XPath processor (like JavaScript XPath engine) to define the neural network model for image tagging.
Lazy web crawling Since our goal is to find the data on a set of web pages (for example API portal), we need to add facilities to deal with these. We propose the addition of a new axis link::* that connects any attribute or text containing URL with the link target.

Thus //a/@href/link::* would follow any (and all) href links in the document. We note that following link::* or constructing a URL with link() function would be the only way to reach elements on an alternate web page.

4 InferXPath meta-language

On top of the declarative language XPath with browser extensions (XPath-BE) we build language that operates on node sets and the XPath-BE expressions themselves.

4.1 Semantic sets

Node sets are first created by semantic set finding. Typical semantic sets recognised on pure textual basis may be numbers, currency amounts, HTTP transfer methods, or JSON expressions. After preprocessing to identify these, we match each semantic value with the root node of its subtree on the web page. Thus we receive several starting semantic sets. We can also subdivide these semantic sets into subsets by the DOM tree structure on the page. Another way of describing semantic nodes perhaps just offering an XPath that matches them, for example //dd will match all definiens nodes of definition lists within a document.

4.2 Relations

When analysing relations between elements on a web page, it is common to use XPath expressions travelling from the current node to another. Indeed numerous tools facilitate this process. We build on this to provide a language that takes two sets of values $A$ and $B$, we need a function allPaths($A, B$) that finds the simplest path description between two sets of values. To simplify the matter, we can either use unique node identifiers for $A$ and $B$ sets, or XPath expression that finds these sets.

Path reconstruction operators

1. For a given answer set, finding a set of XPaths that refer to it:
   - allPaths(//*[contains(text(), "GET")]) - enumerates XPaths that refer to a given set of elements for a given set of web pages

   \[4\] Or //element::a/attribute::href/link::*
samplePaths(//*[contains(text(), "The first example")]) - enumerates XPaths that have a given element somewhere in the answer set

2. We order the XPaths by the preference function of Path Complexity described in the next section

3. We also provide operations that filter out all undesired paths:
   - withPrefix(//h1) - all paths that start with a given path or from a given elements (thus having this answer set at the start of the prefix)
   - byAxis::attribute - path that starts with given axis (which can be combined: byAxis::attribute(byAxis::child-of)

4. We also defined the postprocessing functions:
   - dropPrefix(//h1) - drop prefix that has a given answer set as a result

5. We also define a function that forces searching for a path only within a subtree of a web page:
   - withinPrefix(/body/div[@id='content']) would constrain our search to within the <div/> element that contains the main content of the document.

Note that the key to implementing efficient path reconstruction is allowing the combination of XPath complexity preference function and path reconstruction operators on whole sets of possible XPaths, and thus quickly narrowing the search tree to the subset of operators. When returning result we compute these lazily and only return first N results

Path complexity preference function

We present the following preferences:

- We prefer the axes in the following order:
  1. child::* or attribute::*
  2. following-sibling::* and preceding-sibling::*
  3. descendant::* Note that this preference function can be reformulated simpler: we always prefer axes going downward in the tree (stratification), and then those axes that have fewer direct connections (limiting search options) One can convert it into an algorithm by only generating preferred expressions first
- In case that result occurs on a single level of the tree, we prefer paths that do not include axes that may jump multiple levels (following::*
- Finally we prefer shorter paths over the longer ones.

Now please note that giving the desired result as answer set means that we can enumerate connecting XPaths in reverse order:

- first attempting to go upwards,
- then going backwards in the tree by the axes that give the fewest options

---

5 This is easier to implement than making sure the process finishes quickly or at all.
6 Parts of this module will likely be implemented by Migamake, if it proves to be too difficult.
Discussion

We propose the expansion of XPath with both new relations between nodes that correspond to the rich semantics of the HTML Document Object Model, and meta-level functions that allow us to infer the most straightforward possible schema for the data structure of the web page. This is with an eye on applications similar to translation of REST API HTML documentation web pages into relation tables[1].

We also note that the finding of optimal XPath for a given application is a common activity of website programmers and scrapers alike, so the declarative metalanguage for inferring XPath-BE expressions allows for wide set of future applications.

This meta-level reasoning is facilitated by node-set semantics of classical XPath, and allows us to reformulate website schema discovery as finding simplest XPath expressions that allow us to navigate between different sets of nodes.

This work-in-progress report may also be interesting for researchers of XPath and tree-processing languages that consider future extensions of these that expand the range of practical applications. We observe that these extensions greatly increase ergonomics, and are hard to emulate with purely tree-structure-oriented processing which is used by conventional XPath and CSS selectors.

Acknowledgments

Implementation of this proposal is a joint work in progress by Migamake and KikaiTech to automate laborious scraping tasks.

Bibliography

[1] Agile generation of cloud api bindings with haskell: 2020. https://www.youtu.be/watch?v=KY27LsV11Rg. Accessed: 2020-08-10.
[2] Clark, J. and (eds.), S.D. 1999. XML Path Language (XPath) Version 1.0. W3C.
[3] Crescenzi, V. and Mecca, G. 2004. Automatic information extraction from large websites. J. ACM. 51, (2004), 731–779.
[4] DOM, Living Standard: https://dom.spec.whatwg.org/.
[5] He, K. et al. 2016. Deep residual learning for image recognition. 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR). (2016), 770–778.
[6] Krizhevsky, A. et al. 2017. ImageNet classification with deep convolutional neural networks. CACM (2017).
[7] Lemay, A. 2018. Machine learning techniques for semistructured data. (2018).
[8] Nestorov, S. et al. 1998. Extracting schema from semistructured data. Proceedings of the 1998 ACM SIGMOD International Conference on Management of Data (New York, NY, USA, 1998), 295–306.
[9] Quass, D. et al. 1997. Querying semistructured heterogeneous information. *Journal of Systems Integration*. 7, (1997), 381–407.

[10] Ramakrishnan, G. et al. 2008. Using ilp to construct features for information extraction from semi-structured text. *Inductive logic programming* (Berlin, Heidelberg, 2008), 211–224.

[11] Simonyan, K. and Zisserman, A. 2015. Very deep convolutional networks for large-scale image recognition. *CoRR*. abs/1409.1556, (2015).

[12] Szegedy, C. et al. 2017. Inception-v4, inception-resnet and the impact of residual connections on learning. *AAAI* (2017).

[13] WebDriver, W3C Recommendation: https://www.w3.org/TR/webdriver1/.