Data acquisition, extraction, and storage

Structured content extraction from the Web

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10 October 2025

Outline

Objective

- Assume you have crawled a somewhat homogeneous collection of Web pages with information of interest
- Given a Web page (or a collection) with a fixed structure, how to extract information of interest?
- Sometimes, extraction and crawling are interleaved (you need to know extracted content to determine what next to crawl)
- But usually good idea to crawl first, explore later (avoid having to recrawl if the extraction process changed)
- Web scraping: Entire crawl and extraction process

Wrapper

Wrapper: program (usually written in some specialized language) that extracts data from semi-structured (usually HTML) documents and turns it into a structured form (CSV, relational data, XML or JSON with fixed structure, etc.)

Wrapper induction: process of building or learning an appropriate wrapper for a collection of similarly structured documents

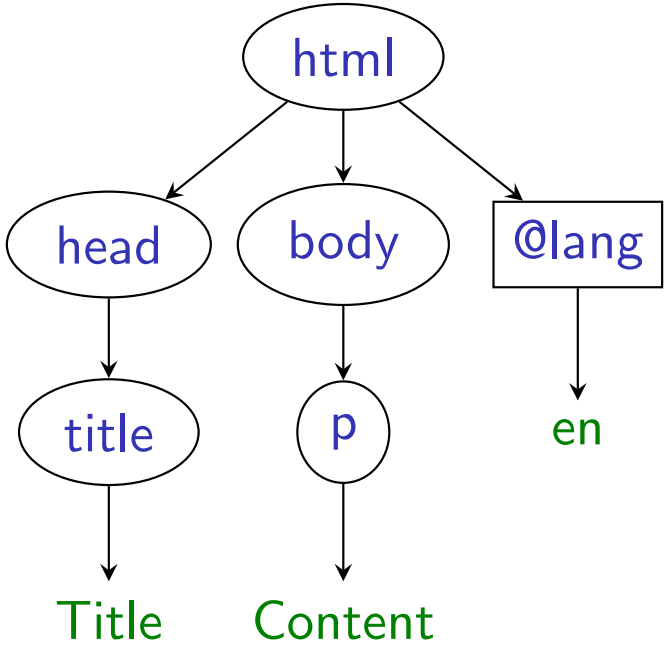
Selector: expression in a domain-specific language that is used by the wrapper to pinpoint certain regions of interest in a semi-structured document

Document Object Model (DOM)

Tree representation of an HTML document, suitable for manipulation and extraction.

Example

```
<html lang="en">
  <head><title>Title</title></head>
  <body><p>Content</p></body>
</html>
```



Languages for selectors

- Based on serialization: regular expressions (see further)
- Based on DOM:

  DOM navigation expresses local navigation in the DOM, from a node to its parent, its children, its attribute, etc. Standard API [WHATWG, 2021] but variations.

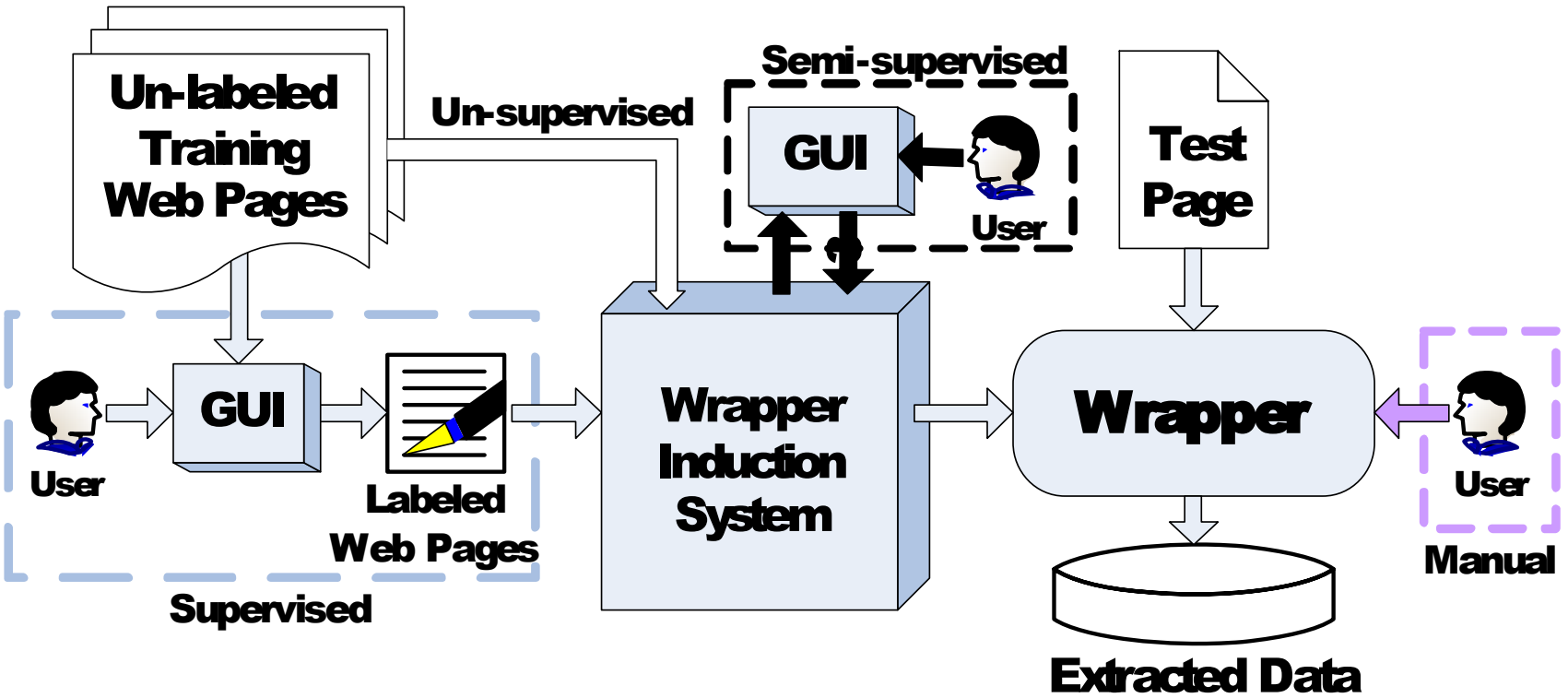
  searching elements by tag names, identifiers, names, class names

  CSS selectors (see further)

  XPath (see further)

Sometimes combined! For instance, use XPath to quickly navigate the DOM, then a regular expression to extract substrings.

Types of wrapper induction [Chang et al., 2006]



Supervised, semi-supervised, and domain-based techniques

- Many academic approaches and systems, see [Ferrara et al., 2014] for a survey
- No ready-to-use free software for supervised and semi-supervised extraction (as far as I know)
- Existing companies selling wrapper induction software
- Promising start-ups exploiting these ideas – Lixto (semi-supervised), Wrapidity (domain-based) – sold to big media intelligence groups (McKinsey, Meltwater, respectively)

Unsupervised techniques

- Exploiting data redundancy within a page [Liu et al., 2004] or across pages [Crescenzi et al., 2001, Arasu and Garcia-Molina, 2003]
- RoadRunner: one of the first such systems, freely downloadable and existing demos at `http://www.dia.uniroma3.it/db/roadRunner/`
- Usually, no labels provided by the extraction, non-trivial problem
- Nowadays: an LLM may infer for you appropriate CSS/XPath selectors, but no guarantees, and be careful of edge cases

Manual techniques

- Write a wrapper by hand, using one wrapper language (itself relying on a selector language to indicate which data to extract)
- scrapy (which also has crawling and browser simulation features) can be used to write wrapper (relying on the parsel library to support CSS and XPath selectors)
- Alternatives: BeautifulSoup in Python, regular expression or XPath libraries in arbitrary programming languages, etc.
- XSLT, a programming language for transforming XML documents, is also great for this task! `http://webdam.inria.fr/Jorge/files/wdm-pip-xslt.pdf`
- Browser instrumentors like Selenium (or Playwright, Puppeteeer) can also be made to extract data (e.g., through JS code making use of XPath expressions), since they control the browser

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Regular Expressions

- Apply to the serialized representation, not to the DOM tree.
- Available in a wide range of host languages (including Python with the `re` package).
- The following characters are metacharacters.

```
? * + | ( ) ^ $ . [ ] { } " \
```

- Metacharacters have special meaning; they do not represent themselves.
- All other characters represent themselves.

Operators

r	One occurrence of r
$r?$	Zero or one occurrence of r
$r*$	Zero or more occurrences of r
$r+$	One or more occurrences of r
$r \mid s$	r or s
rs	r concatenated with s

r and s are regular expressions.

Grouping and extra symbols

- Parentheses are used for grouping.
- The expression

  ```
  ("+"|"-")?
  ```

  represents an optional plus or minus sign.
- If a regular expression begins with `^`, then it is matched only at the beginning of a line or string (depending on context).
- If a regular expression ends with $, then it is matched only at the end of a line or string (depending on context).
- The dot `.` matches any non-newline character.

Character groups

- Brackets `[ ]` match any single character listed within the brackets.
- For example,
  - `[abc]` matches `a` or `b` or `c`.
  - `[A-Za-z]` matches any letter.
- If the first character after `[` is `^`, then the brackets match any character *except* those listed.
  - `[^A-Za-z]` matches any nonletter.

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CSS

- CSS: Cascading StyleSheets
- W3C recommendation
- History: CSS1 (1996), CSS2 (1998), CSS2.1 (2005), CSS3 (continuously developed and updated since 1999, decomposed into modules, each module having its own version number, named level)
- Somewhat disparate support by browsers, see `https://caniuse.com/`
- Here: focus on CSS selectors [W3C, 2022] – and in particular those supported by the cssselect Python library, itself used by parsel and thus scrapy

CSS and HTML

- HTML describes structure and content
- CSS describes: text formatting and layout of blocks with respect to one another

Simple, multiple, universal selectors

Simple selector: tag name

Multiple selector: several selectors joined by commas

Universal selector: '*', selects everything

Examples

- `ul` selects unordered lists
- `h1,h2,h3,h4,h5,h6` selects all section titles
- `*` selects everything

Class selectors

Class selector: class name, prefixed with '`.`', as it appears in a `class` attribute of an HTML tag

Examples

- `.person` selects all tags with class `person` (and possibly other classes)
- `p.comment` selects all <p> tags with class `comment`

Identifier selector

Identifier: as defined by the `id` attribute of an HTML tag. Similar to classes, but only one tag with a given `id` in the whole HTML document

Identifier selector: identifier name, prefixed with '#', as it appears in the `id` attribute of an HTML tag

Examples

- `#introduction` selects the tag with identifier `introduction`
- `p#introduction` selects the <p> tag with identifier `introduction`

Contextual selectors

Contextual selector: 2 selectors or more separated by spaces. $A\ B$ selects B's only if they are contained in A's

Child selector: 2 selectors separated by >. $A > B$ selects B's children of A's

Next sibling selector: 2 selectors separated by +. $A + B$ selects B's that are the next sibling of an A

Subsequent sibling selector: 2 selectors separated by $\sim$. $A \sim B$ selects B's that are a following sibling of an A

Examples

- `h1 em` selects text in emphasis within a main title
- `ul ol, ol ul, ul ul, ol ol` selects nested lists

Pseudo-class

Pseudo-class: specify some external properties of a class

Examples

- `article > p:first-child` selects all paragraphs that are first children of an <article>
- `article > p:nth-child(2)` selects all paragraphs that are second children of an <article>

Attribute selectors

Based on the presence or value of an attribute.

Examples

- `p[class]` select all paragraphs with a `class` attribute
- `p[class="bar"]` select all paragraphs with a `class` attribute equal to `bar` (different from `p.bar` !)
- `p[class^="bar"]` select all paragraphs with a `class` attribute starting with `bar`
- `p[class*="bar"]` select all paragraphs with a `class` attribute containing with `bar`

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XPath

cf. separate set of slides

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