05 – Indexing and Searching Very Large Texts

IA161 Advanced Techniques of Natural Language Processing

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1. Indexing

2. Searching

Searching big text corpora

Corpus:

- positional attributes – word form, lemma, PoS tag, ...
- structures and structure attributes – documents (e.g. with author, id, year, ...), paragraph, sentence
- searching: Manatee/Bonito/Sketch Engine
- `http://corpora.fi.muni.cz`
- `https://app.sketchengine.eu`
- SQL unsuitable (independent rows)

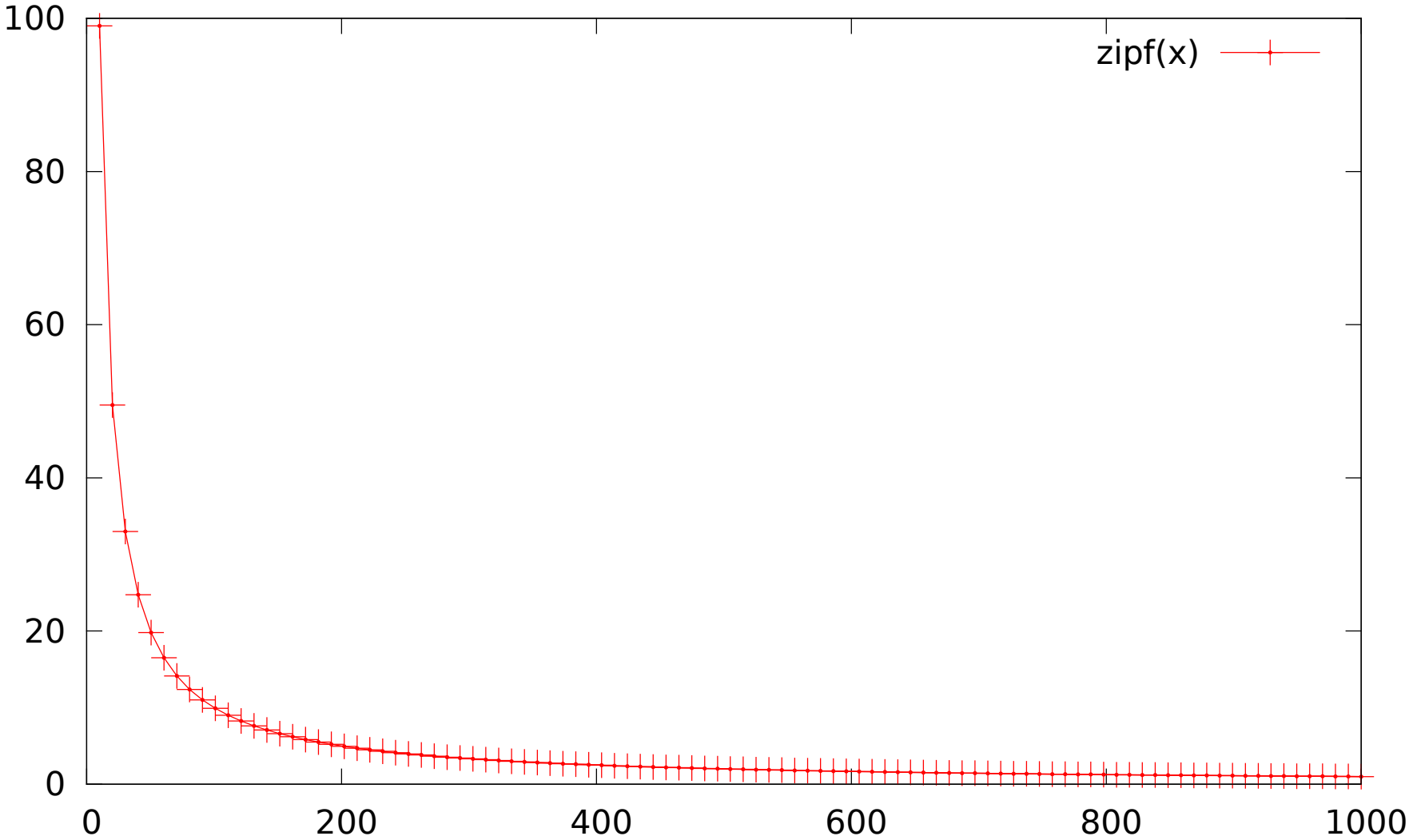
Searching big text corpora

- data too big to be stored in memory
- data too big to be search sequentially

$\Rightarrow$ preprocessing needed (indexing, alias corpus compilation)

- key decisions are:
  - trade off between compile-time (preprocessing) and run-time
  - trade off between in memory and off-memory processing

Zipf's law I



Zipf's law II

- may be simplified to inductive definition:

Zipf's law (simplified)

frequency of the n-th element $f_n \approx \frac{1}{n} \cdot f_1$

- $\Rightarrow$ frequency is inversely proportional to the rank according to frequency
- $\Rightarrow$ one needs really large corpora to capture all the variety of many language phenomena

Zipf's law III

	Word	↓ Frequency [?]		Word	↓ Frequency [?]		Word	↓ Frequency [?]
1	the	174,935,080	11	i	23,989,001	21	not	14,421,888
2	of	88,596,331	12	on	20,237,809	22	or	13,599,707
3	and	80,072,865	13	with	19,230,246	23	have	13,540,277
4	to	77,354,235	14	as	19,076,719	24	at	13,282,835
5	a	59,410,937	15	be	18,269,437	25	he	12,821,501
6	in	54,044,533	16	was	16,505,649	26	from	12,285,435
7	that	34,942,237	17	this	16,475,525	27	but	11,049,177
8	is	34,190,792	18	you	16,268,767	28	we	10,997,497
9	for	27,849,928	19	are	15,838,329	29	they	10,388,785
10	it	24,609,587	20	by	14,917,197	30	an	10,182,791

enTenTen2008, 3.2G tokens

Zipf's law IV

About 1 billion words is enough to have enough evidence for single word units. But not for multiwords:

word	**Brown (1M)**	**BNC (100M)**	**enTenTen08 (2.7G)**	**enTenTen15 (15.7G)**
carbonation	0	5	429	2,817
weird phrase	0	0	14	34

Building corpora

1. content definition (what will it be used for? how do I get texts?)
2. obtaining data (e.g. crawling)
3. data cleaning (spam, boilerplate, duplicates)
4. tokenization
5. sentence segmentation
6. further annotation (PoS tagging)
7. corpus indexing and analysis

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Corpus indexing

- text corpus is a database
- standard (=relational) database management systems are not suitable at all
  - text corpus does not have relational nature
- special database management systems needed

$\Rightarrow$ Manatee

Indexing corpora in Manatee

Key data structures for a positional attribute:

- lexicon
  - because operations on numbers are just so much faster than on strings
- corpus text
  - to iterate over positions
- inverted (reversed) index
  - to give fast access to positions for a given value

How to store integer numbers

- given Zipf's distribution: fixed-length storing very inefficient
- variable-length more complicated but yielding much smaller and quicker indices
- variable-length bit-wise universal Elias' codes: gamma, delta codes
- cf. Huffman coding

Indexing corpora in Manatee

Structures and operations:

- operations in between: string (`str`) – number (`id`) – position (`poss`)
- lexicon building: ⇒ word-to-id mapping ⇒ operations on numbers, not strings ⇒ `id2str, str2id`
- inverted index: `id2poss`
- corpus text: `pos2id`
- yields transitively also `pos2str, str2poss`

Searching corpora in Manatee

- key idea: operations on sorted forward-only streams of positions
- FastStream – single position stream
- RangeStream – stream of position pairs (structures: *from* position, *to* position)

CQL

- = Corpus Query Language (Christ and Schulze, 1994)
- positions and positional attributes: `[attr="value"]`
- structures and structural attributes: `<str attr="value">`
- example:

```
[word=".*ing" & tag="V.*"]
   <doc id="20[5-9].*"
```

- established a `within <str/>` query:

```
[tag="N.*"]+ within <s/>
```

and alternative `meet/union` query:

```
(meet [lemma="take"] [tag="N.*"] -5 +5)
    (union (meet ...)  (meet ...))
```

CQL in Manatee/Bonito

- ehnancements and differences to the original CQL syntax
- `within <query>` and `containing <query>`
- `meet/union` (sub)query
- inequality comparisons
- frequency function

within/containing queries

- searching for particles:

```
[tag="PR.*"] within [tag="V.*"] [tag="AT0"]?
[tag="AJ0"]* [tag="(PR.?|N.*)"] [tag="PR.*"] within
<s/>
```

- searching for a Czech idiom "hnout někomu žlučí" ("to get somebody's goat"):
  word-by-word translated as:
  hnout "move" [V, infinitive]
  někomu "somebody" [N, dative]
  žlučí "bile" [N, instrumental].

```
<s/> containing [lemma="hnout"] containing
[tag=".*c3.*"] containing [word="žlučí"]
```

within/containing queries

- structure boundaries: begin: `<str>`, whole structure: `<str/>`, end: `</str>`
- changes: `within <str>` not allowed anymore, use `within <str/>`

meet/union queries

- combined with regular query: <s/>

```
containing (meet [lemma="have"] [tag="P.*"] -5 5)
containing (meet [tag="N.*"] [lemma="blue"])
```

- changes: meet/union queries can be used on any position, they can contain labels and no MU keyword is required (and deprecated):
  `(meet 1:[] 2:[]) & 1.tag = 2.tag`

Inequality comparisons

- former comparisons allowed only equality and its negation: `[attr="value"] [attr!="value"]`
- inequality comparisons implemented: `[attr<="value"] [attr>="value"] [attr!<="value"] [attr!>="value"]`
- intended usage: `[tag="AJ.*"] [tag="NN.*"] within <doc year>="2009">`
- sophisticated comparison performed on the attribute value: `<doc id<="CC20101031B">` matches e.g. `BB20101031B`, `CC20091031B`, `CC20101030B` `CC20101031A`.

Fixed string comparisons

- normally the CQL values are regular expressions
- sometimes this is not desirable (batch processing needs escaping of metacharacters)
- new == and !== operator introduced for fixed strings comparison
- no escaping needed except for ”’ and '\'
- examples: ”.”, ”$”, ” ” matches a single dot, dollar sign and tilda, respectively, ”\n” matches a backslash followed by the character n,

Frequency function

- a frequency constraint allowed in the global conditions part of CQL:
  `1:[tag="PP.*"] 2:[tag="NN.*"] & f(1.word) > 10`

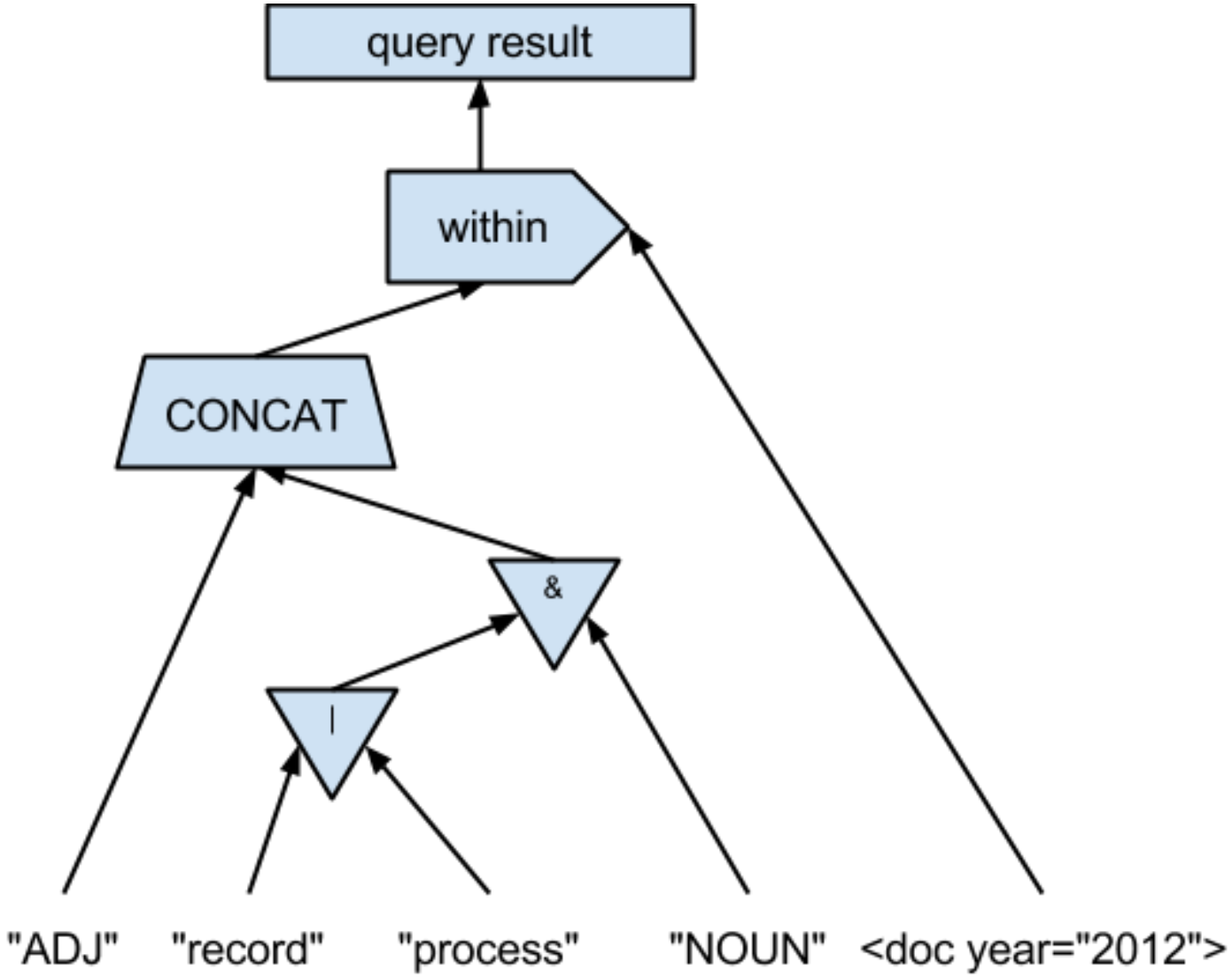
Performance evaluation

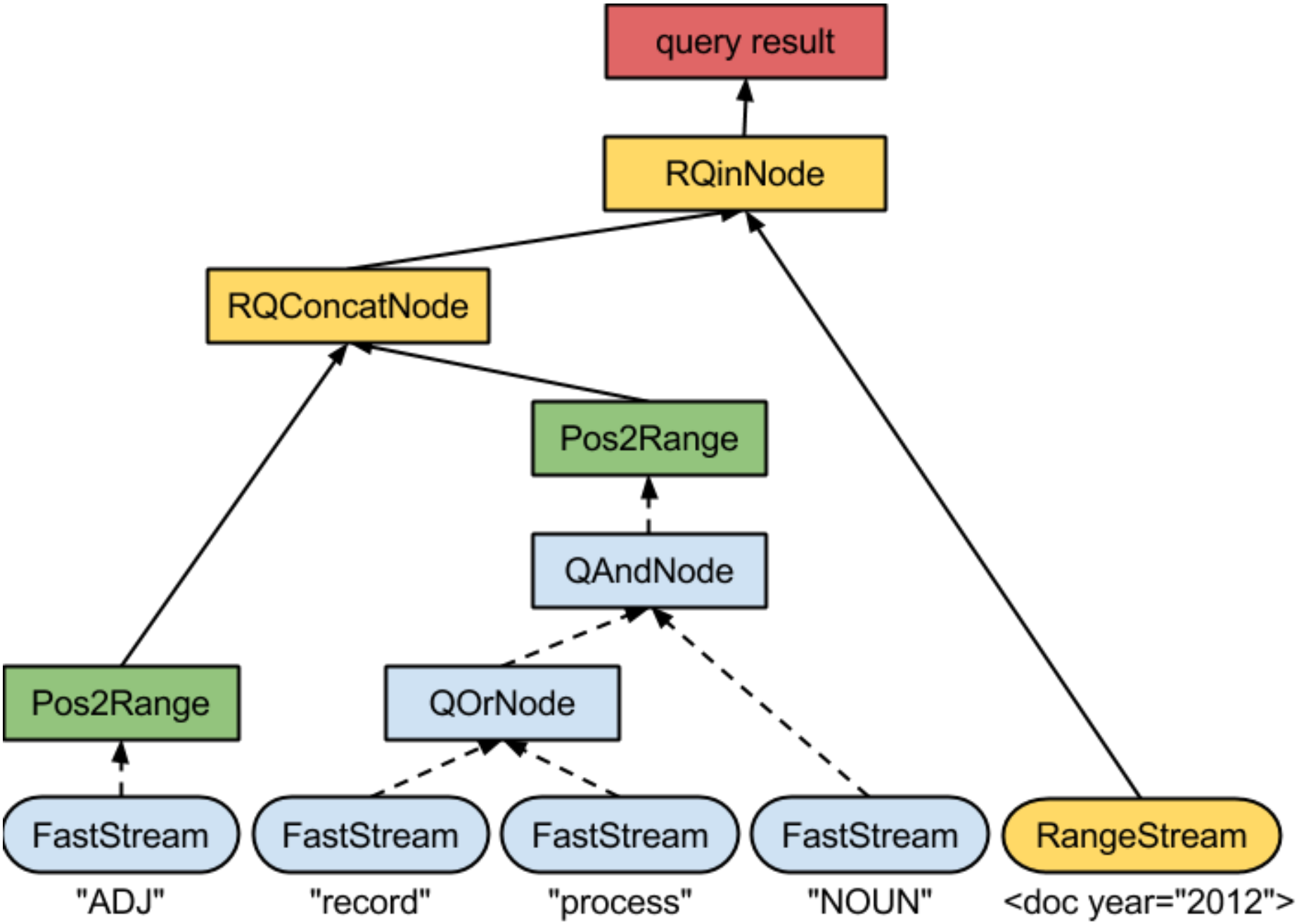
Table: Query performance evaluation – corpora legend: ∘ BNC (110M tokens), • BiWeC (version with 9.5G tokens), ∗ Czes (1.2G tokens)

query	# of results	time (m:s)
∘ `[lemma="time"]`	179,321	0.07
∘ `[lemma="t.*"]`	14,660,881	3.12
∘ Ex: particles	1,219,973	33.36
• Ex: particles	97,671,485	32:26.48
∗ Ex: idioms	66	1:6.86
∘ Ex: meet/union	3	8.47
• Ex: meet/union	1457	7:13.12

CQL query evaluation

Example: `[tag="ADJ"] [(word="record" | word="process") & tag="NOUN"] within <doc year="2012"/>`




query result
RQinNode
RQConcatNode
Pos2Range
QAndNode
Pos2Range
QOrNode
FastStream
FastStream
FastStream
FastStream
RangeStream
"ADJ"
"record"
"process"
"NOUN"
<doc year="2012">

Conclusions

- special database management systems for processing text corpora needed
- trade-offs between compile-time and run-time, in-memory and off-memory
- CQL
- Manatee

Assignment