Text Retrieval Based on Medical Subwords

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Problem:

Poor performance of medical text retrieval in morphologically rich languages*

*most languages other than English

Linguistic Phenomena hamper Medical Text Retrieval

- Word formation

  (inflection, derivation, composition):

  ulcus, ulcera, diagnosis, diagnoses, diagnostic, hepar, hepatic, para|sympath|ectomy, proct| o|sigmoid|o|scop|ie, Rechts|herz|insuffizienz

- Synonymy, spelling variants

  {oesophagus, esophagus}, {leuko, leuco}, {Magenulcus, Magenulkus}, {cutis, skin}, {hemorrhage, bleeding}, {ascorbic, Vitamin C}, {ancylostoma, hookworm}

- Multiple meanings:

  Cold {low temperature, common cold}, Bruch {fracture, hernia}, APA {antiperoxidase antibodies, american psychology association}

Example

- Frequency of German Word forms in *Google* Searches

Spelling Variants Synonyms			Inflections			Derivations		
Kolonkarzinom	2070	1780	**Kolonkarzinom**	2070	1770	**Karzinom**	17000	16900
Colonkarzinom	248	135	**Kolonkarzinoms**	471	253	**karzinomatös**	43	16
Coloncarcinom	111	73	**Kolonkarzinome**	275	139	**karzinomatösen**	86	40
Colon-Ca	203	169	**Kolonkarzinomen**	265	166	**karzinomatöse**	74	46
Kolon-Ca	66	46				**karzinomatösem**	7	5
Dickdarmkrebs	4000	3610				**kazinomatöses**	6	0
Dickdarmkarzinom	288	175				**karzinomatöser**	39	26
Dickdarmcarcinom	13	10						

Number of Hits

Number of exclusive hits (no other form matches)

Hypothesis:

Improving Text Retrieval Performance using Linguistic Techniques

Subword as Index Terms for Text Retrieval

- Subwords are atomic linguistic sense units :
  - Morphemes: *nephr, anti, thyr, scler, hepat, cardi*
  - Morpheme aggregates: *diaphys, ascorb, anabol, diagnost*
  - Words: *amyloid, bone, fever, liver*
  - (noun groups: *vitamin c*,…)
- Criterion: well-defined, non-decomposable medical concepts
- Grouping of synonymous subwords:

  kkyxkj = {*nephr, kidney, nier, ren*},
  qxkjkq = {*hepar, hepat, liver*},

Resources

- Subword lexicons:
  Organize and classify subwords, prefixes and suffixes in several languages
- Subword thesaurus: Groups synonymous lexicon entries, links „similar“ groups
- Morphosyntactic parser: extracts subwords from text

Cf. Schulz et. al. MEDINFO 2001
Yearbook of Medical Informatics ‘02

Examples of Subword Extraction

- Examples:
  - **proct** o **sigm** oid o **scop** y
  - **Schilddrüs** en **karzin** om
  - **cole cist ectom** ía
  - **acro cefal** o **sindattil** ia
  - **Sport verletz** ung en
  - **hør** sel s **hemm** ed e
  - **orchid** o **pex** ie
  - **Magen schleimhaut entzünd** ung

Lexical subwords (used for indexing)

Functional morphemes (not used for indexing)

Experiment:

Does Subword-based medical text retrieval behave better than conventional methods ?

(formative evaluation - work in progress)

Retrieval Experiments: Sources

- German version of the `Merck Manual´ (medical textbook composed of 5,500 articles)
- 25 randomly chosen expert queries from medical students (German)
- 27 randomly chosen layman queries from the medical search engine *“Dr. Antonius”*
- Gold Standard:
  Three medical students did manual relevance assessment (52 * 5,500 binary relevance judgements)

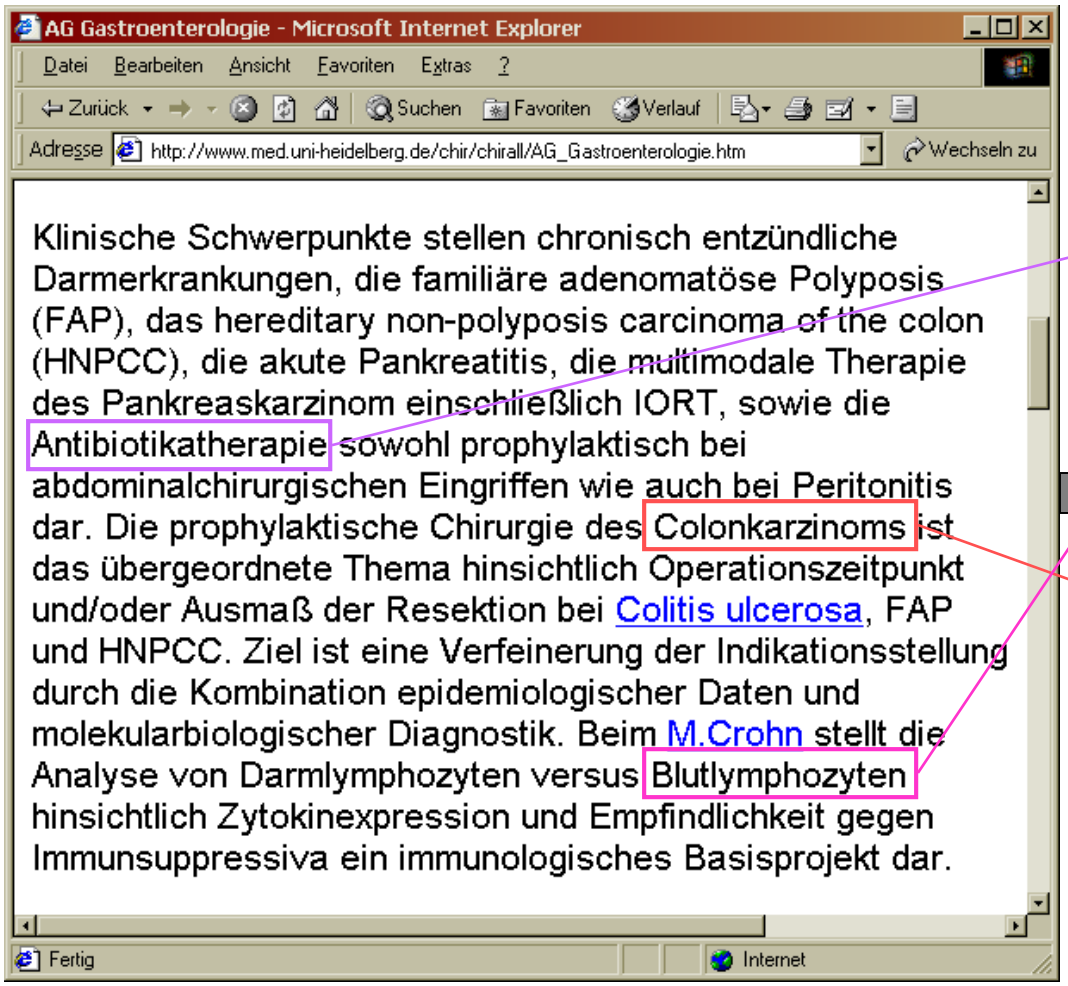
Retrieval Experiments:

- Salton's Vector Space Retrieval Engine (produces ranked output)
- Proximity boost (proximity of query terms in documents matters for document ranking)
- Tests:
  - Test 1 (plain): Token Search. Baseline
  - Test 2 (segm): Morphological Segmentation
  - Test 3 (norm): Morphological Segmentation and Synonym Expansion.

For all tests:

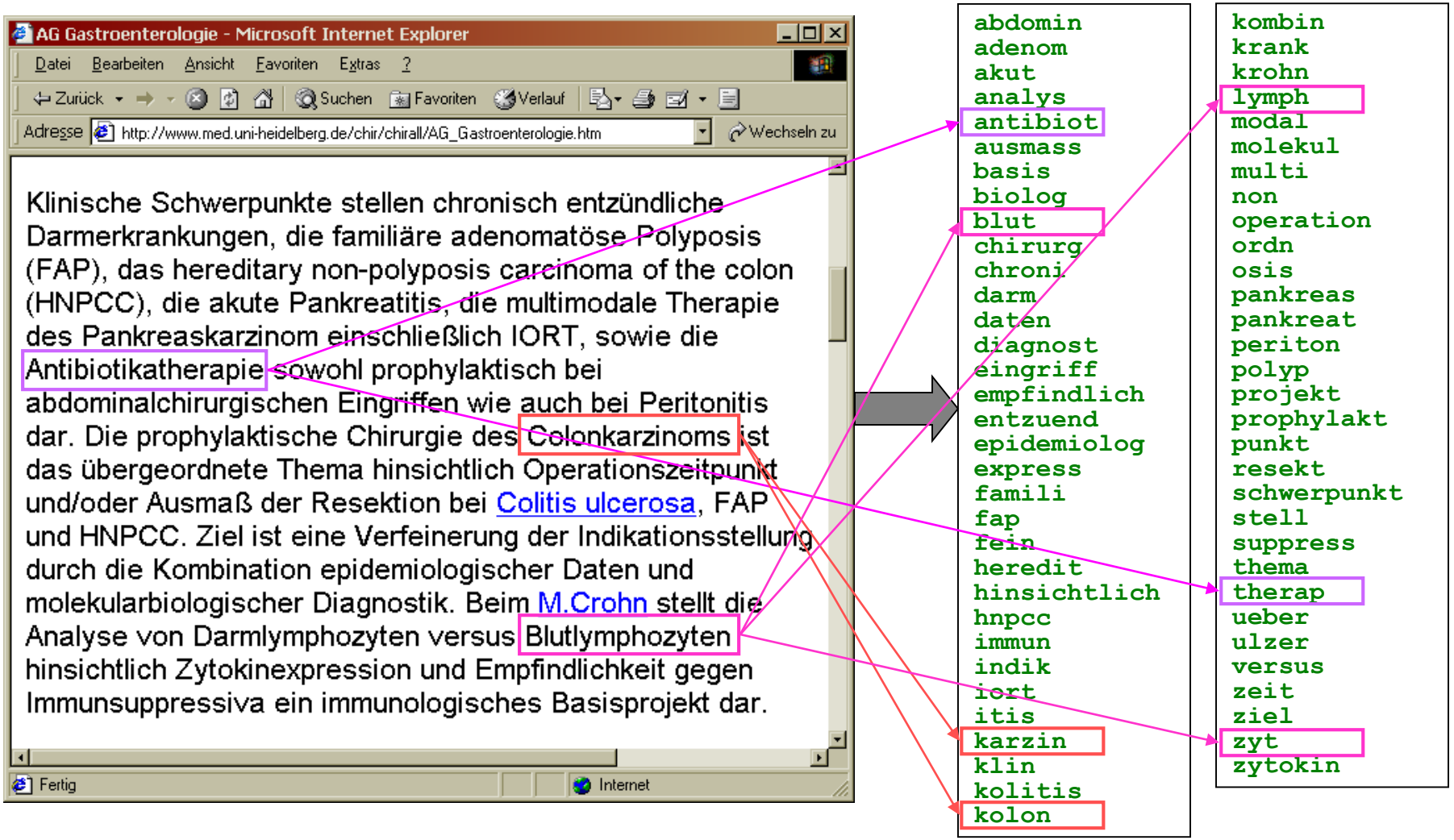
- Orthographic normalization preprocessing (e.g. ca → ka ,ci → zi, ä → ae, …)

Token-based Indexing

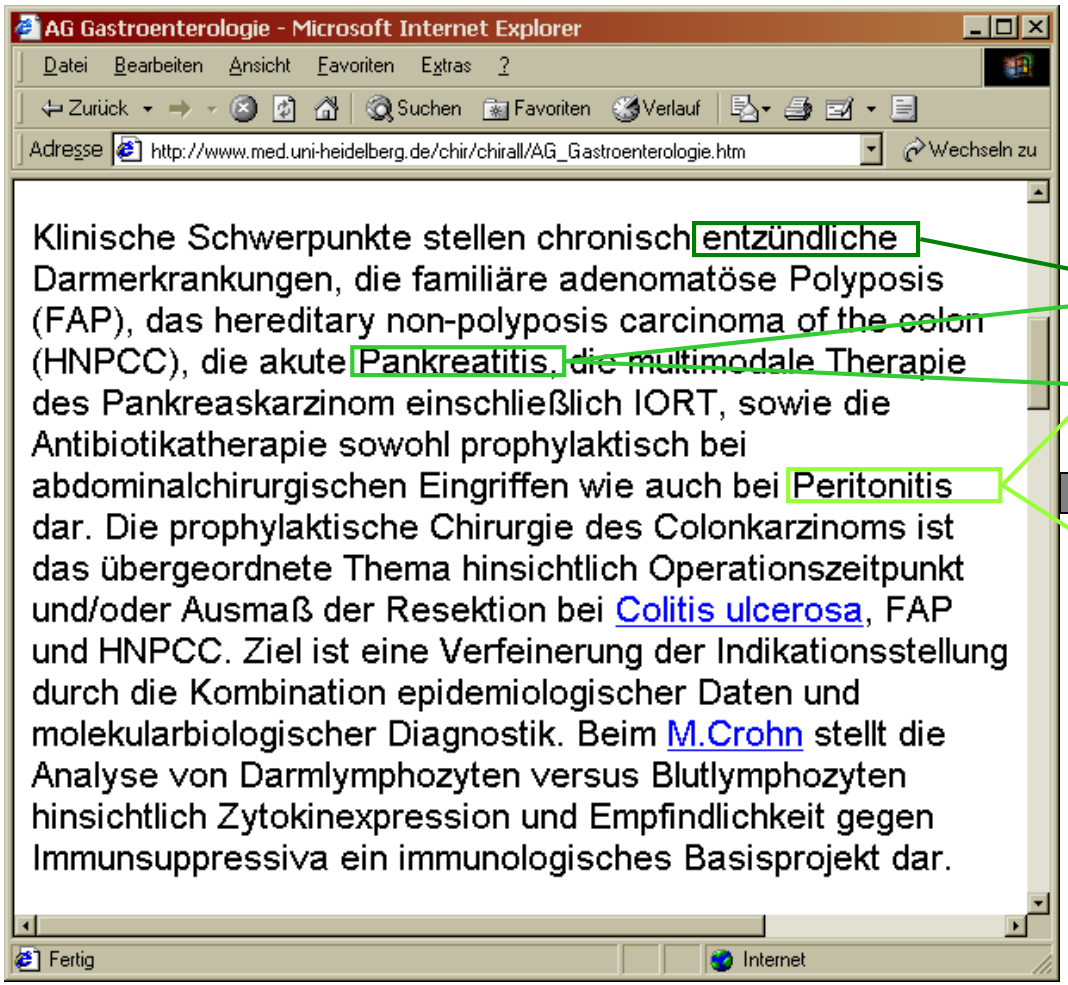


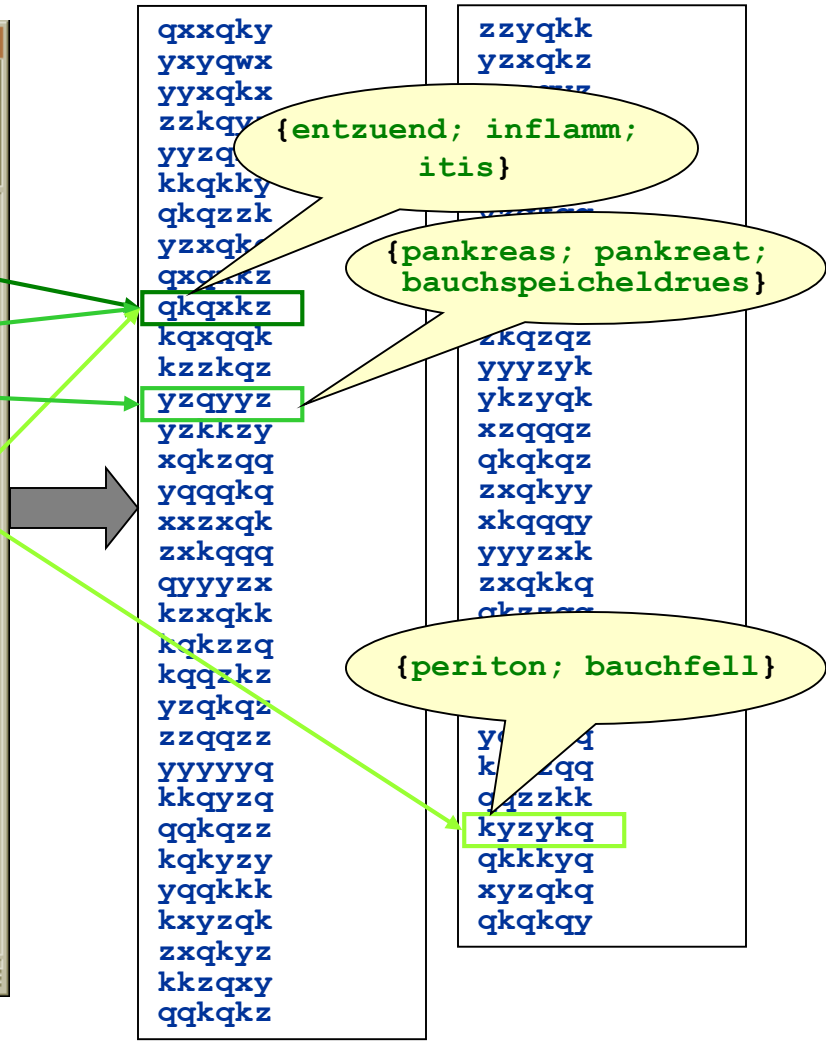

```
abdominalchirurgischen
adenomatöse
akute
analyse
antibiotikatherapie
ausmaß
basisprojekt
blutlymphozyten
carcinoma
chirurgie
chronisch
colitis
colon
colonkarzinoms
darmerkrankungen
darmlymphozyten
daten
diagnostik
eingriffen
einschließlich
empfindlichkeit
entzündliche
```

Subword Indexing



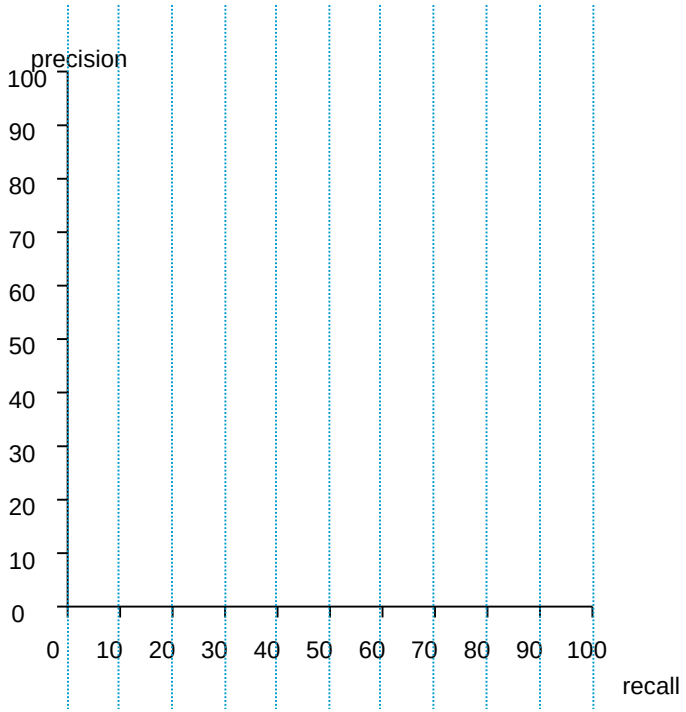
Subword - Indexing with Semantic Normalization



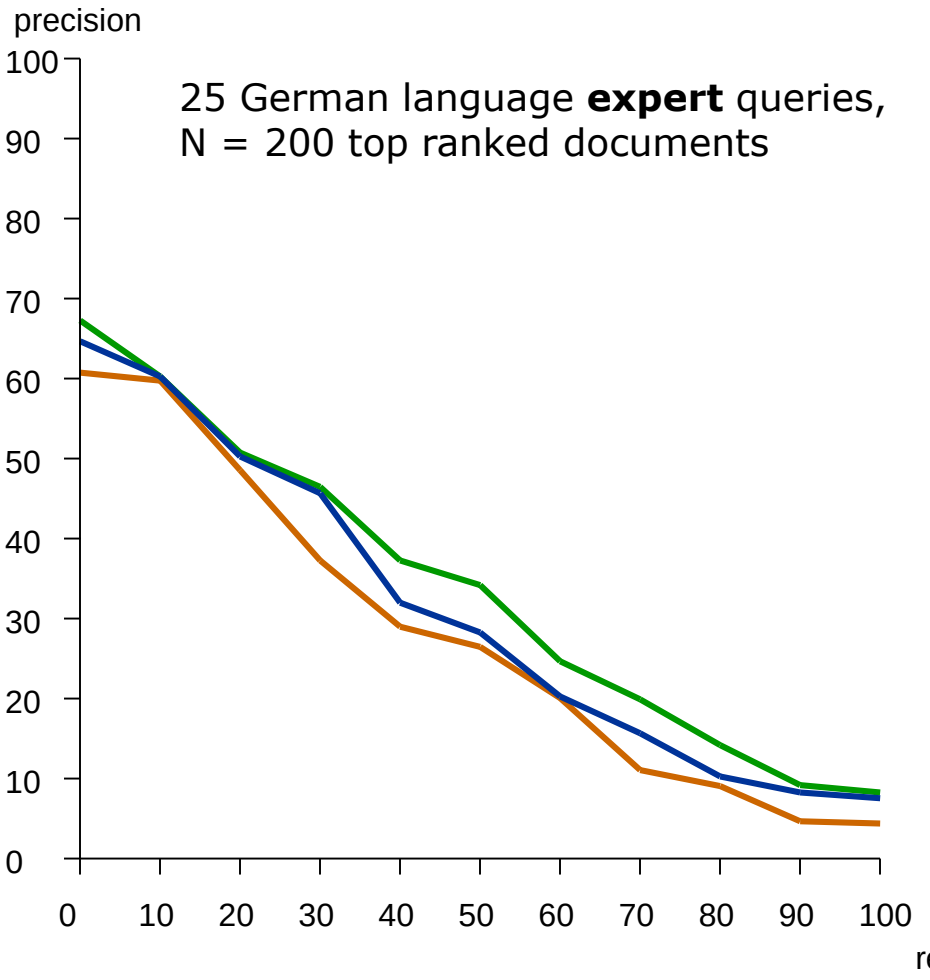


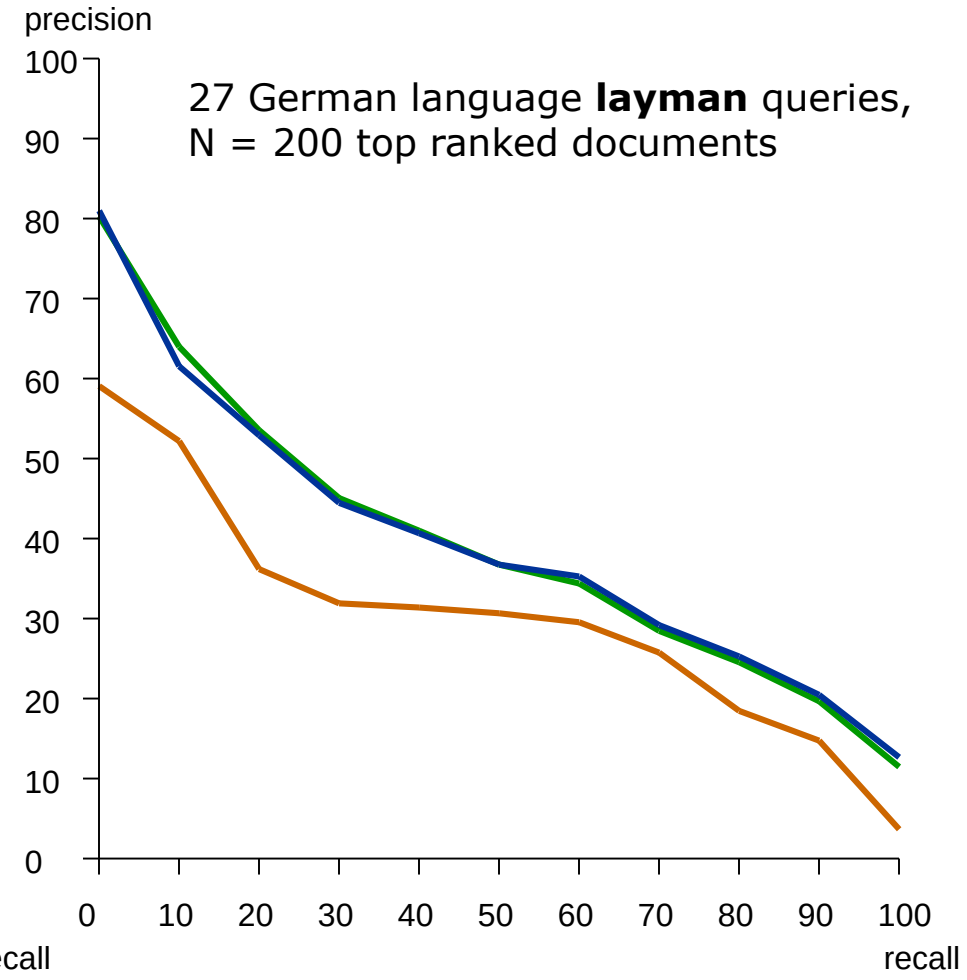
Presentation of Results

- Precision / Recall Diagrams
- For each query: interpolation of precision value at fixed recall levels (0%, 10%,…, 100%)
- Arithmetic mean of precision values at each recall level



Retrieval Experiments: Results





- **Test 1: Token Search (“plain”). Baseline**
- **Test 2: Morphological Segmentation (”segm”)**
- **Test 3: Morphological Segmentation and Synonym Expansion. (”norm”).**

Significance Judgements

Precision (%)									
Recall	*plain*	*segm*	*norm*	*plain*	*segm*	*norm*	*plain*	*segm*	*norm*
(%)	expert queries n=25			layman queries n=27			all queries n=52		
0	60.8	67.3	64.7	59.1	**80.3**	**81.0**	60.0	**74.0**	**73.2**
10	59.8	60.3	60.3	52.2	64.0	61.6	55.8	62.3	61.0
20	48.6	50.8	50.3	36.2	**53.6**	**52.9**	42.1	52.3	51.7
30	37.3	46.5	45.7	31.9	**45.1**	**44.5**	34.5	**45.8**	**45.1**
40	29.0	37.3	32.0	31.4	**41.0**	**40.7**	30.3	39.2	36.5
50	26.5	34.2	28.3	30.7	36.8	36.8	28.7	**35.6**	32.7
60	20.1	24.7	20.3	29.6	34.4	35.3	25.0	29.7	28.1
70	11.1	19.9	15.7	25.8	28.5	29.2	18.7	24.4	22.7
80	9.1	14.2	10.3	18.5	24.6	25.3	14.0	**19.6**	18.1
90	4.7	**9.2**	8.3	14.8	19.7	**20.5**	9.9	**14.7**	**14.6**
100	4.4	**8.3**	7.6	3.7	**11.5**	**12.7**	4.0	**10.0**	**10.2**
11pt avrg.	24.1	33.9	31.2	29.5	40.0	40.0	26.9	37.0	35.8

$\alpha < 0.05$ (Wilcoxon test)

Discussion:

Do the results justify the effort ?

Discussion

- Work in progress
- Coverage of Subword dictionary (core vocabulary of clinical medicine (excl. proper names, acronyms) for German, English, Portuguese, ~ 17,000 entries). Target: 30,000 entries
- Linking subwords by synonymy relations adds noise to the system: more cautious use of synonymy relation
- Noise due to the erroneous extraction of medical subwords from non-medical terms and proper names: inclusion in dictionary

Outlook

- Data-driven improvement of lexicons, thesaurus word grammar, algorithms, disambiguation heuristics
- Automated acquisition of abbreviations and acronyms (WWW)
- Semi-Automated acquisition of proper names
- Linkage to (MeSH): concept hierarchies, synonyms at the level of noun groups
- Evaluation of monolingual retrieval for Portuguese
- Evaluation of cross-lingual retrieval (German - English, English - Portuguese)

Evaluation of Text Retrieval Systems

- Target variables:

$$precision = \frac{n_{found+relevantDocuments}}{n_{found\_documents}}$$

$$recall = \frac{n_{found+relevant\_documents}}{n_{relevant\_documents}}$$

- Precision/Recall-Diagrams with ranked output

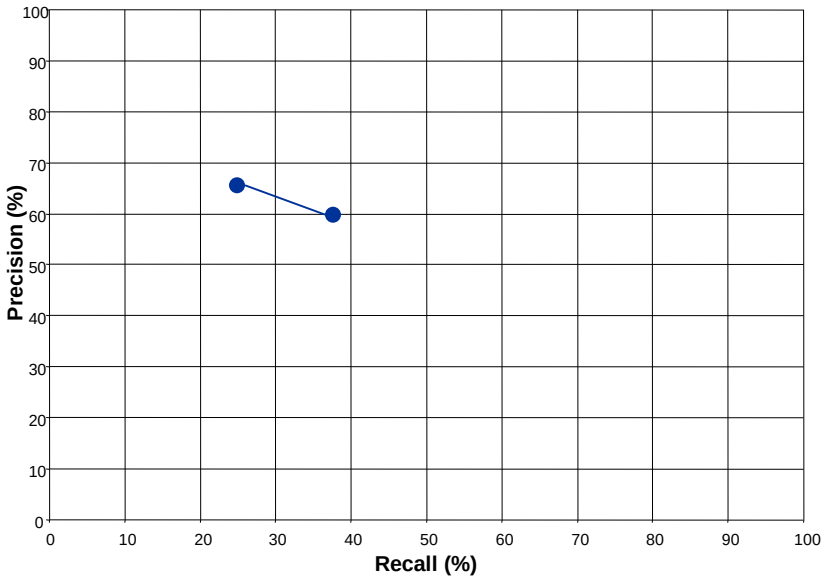
  Example: 25 documents, 8 relevant

Query X

$precision = 67\%$
$recall = 25\%$

document 05
document 16
document 21
document 22
document 02
document 25
document 20
document 10
document 07
document 18
document 04
document 12
document 11
document 24
document 15
document 09
document 17
document 08
document 19
document 13
document 03
document 14
document 23
document 01
document 06

Evaluation of Text Retrieval Systems



Query X

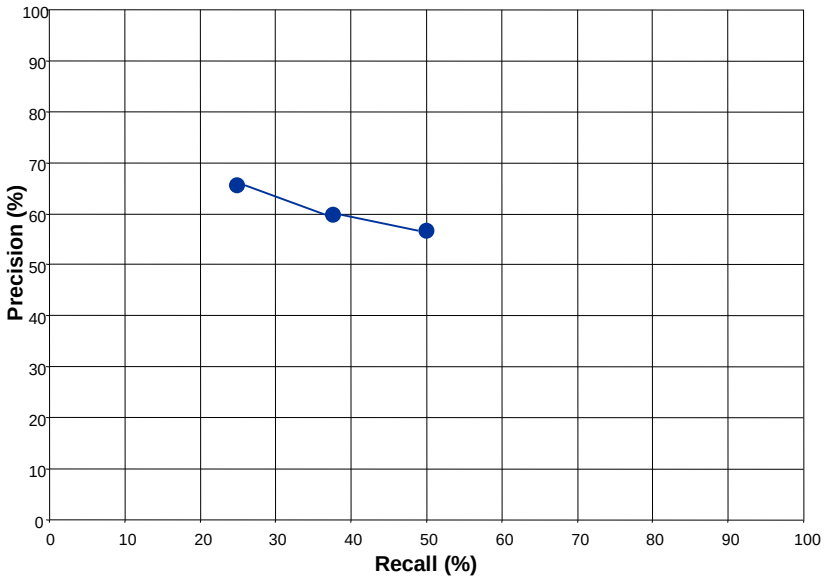
precision = 60%
recall = 38%

document 05
document 16
document 21
document 22
document 02
document 25
document 20
document 10
document 07
document 18
document 04
document 12
document 11
document 24
document 15
document 09
document 17
document 08
document 19
document 13
document 03
document 14
document 23
document 01
document 06

- Precision/Recall-Diagrams with ranked output

  Example: 25 documents, 8 relevant

Evaluation of Text Retrieval Systems



- Precision/Recall-Diagrams with ranked output

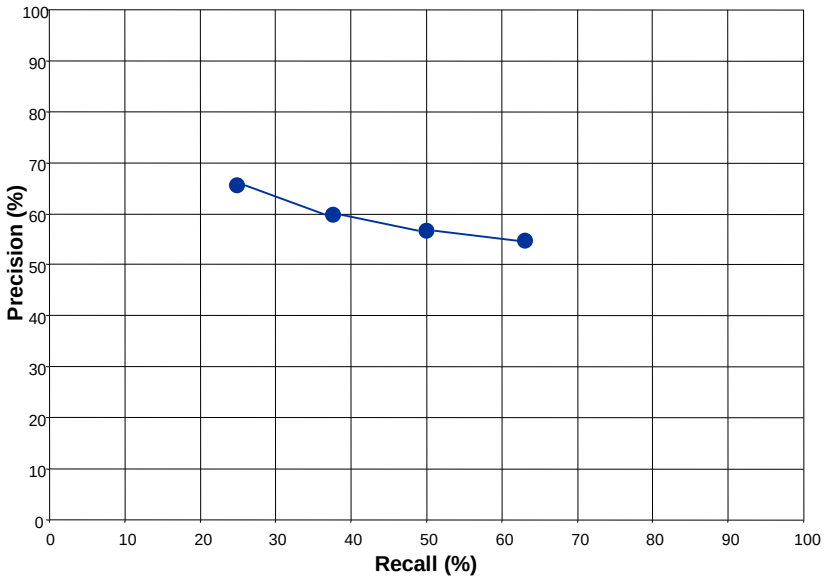
  Example: 25 documents, 8 relevant

Query X

precision = 57%
recall = 50%

document 05
document 16
document 21
document 22
document 02
document 25
document 20
document 10
document 07
document 18
document 04
document 12
document 11
document 24
document 15
document 09
document 17
document 08
document 19
document 13
document 03
document 14
document 23
document 01
document 06

Evaluation of Text Retrieval Systems



- Precision/Recall-Diagrams with ranked output

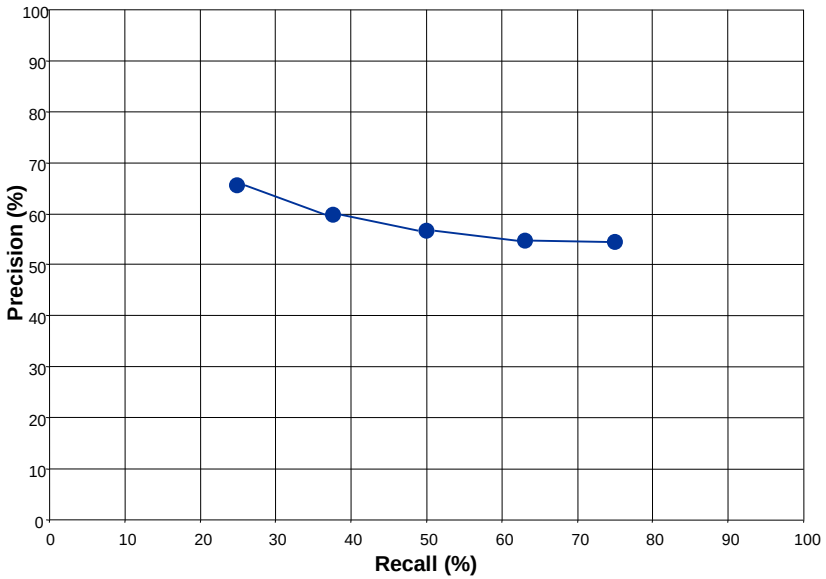
  Example: 25 documents, 8 relevant

Query X

precision = 55%
recall = 63%

document 05
document 16
document 21
document 22
document 02
document 25
document 20
document 10
document 07
document 18
document 04
document 12
document 11
document 24
document 15
document 09
document 17
document 08
document 19
document 13
document 03
document 14
document 23
document 01
document 06

Evaluation of Text Retrieval Systems



- Precision/Recall-Diagrams with ranked output

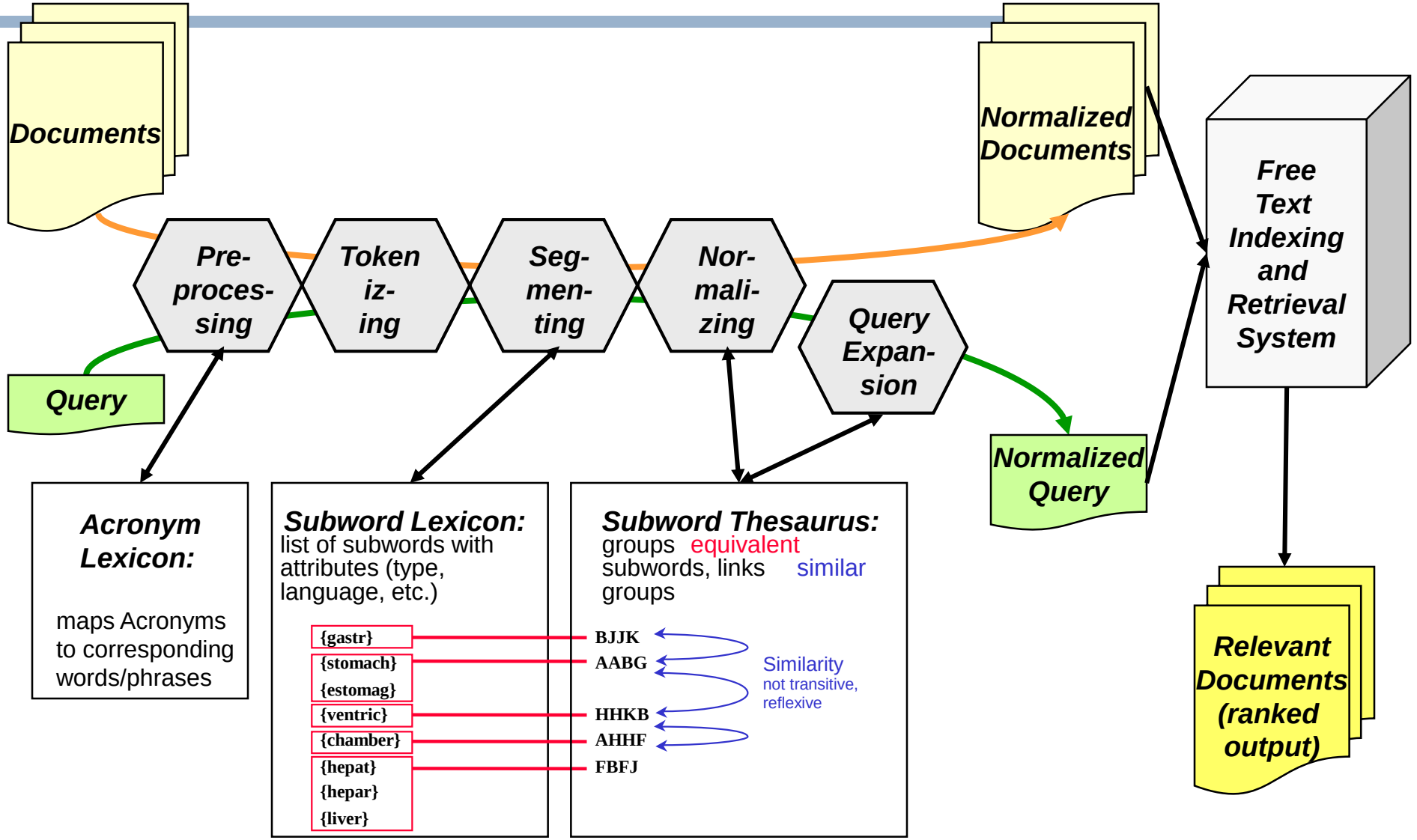
  Example: 25 documents, 8 relevant

Query X

precision = 54%
recall = 75%

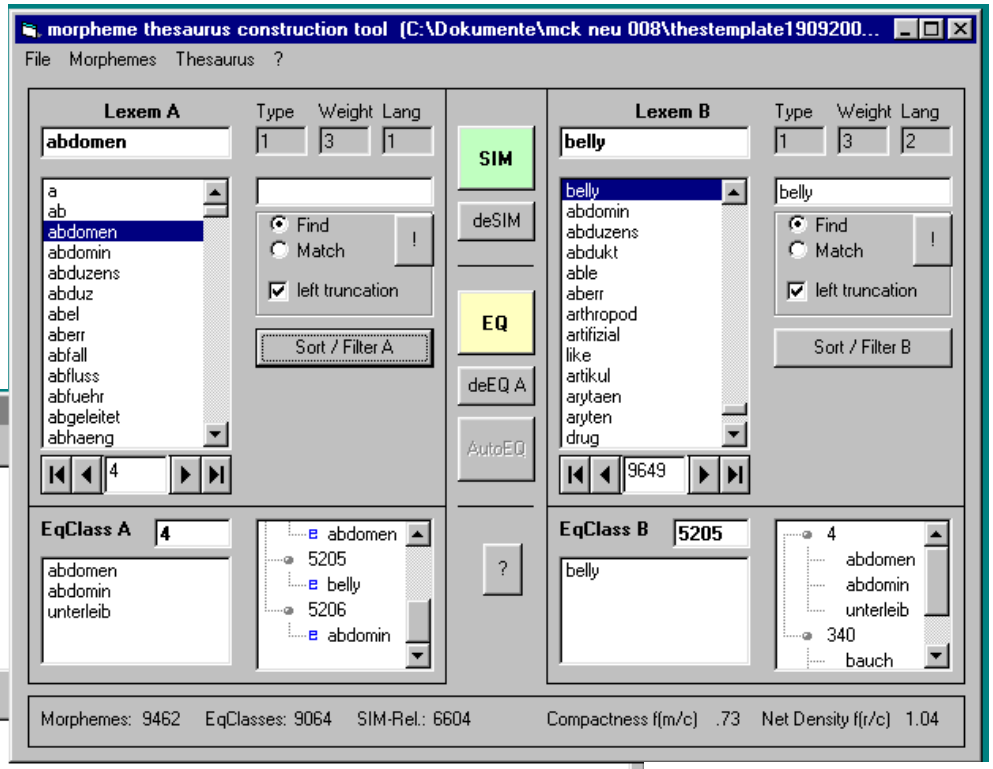
document 05
document 16
document 21
document 22
document 02
document 25
document 20
document 10
document 07
document 18
document 04
document 12
document 11
document 24
document 15
document 09
document 17
document 08
document 19
document 13
document 03
document 14
document 23
document 01
document 06

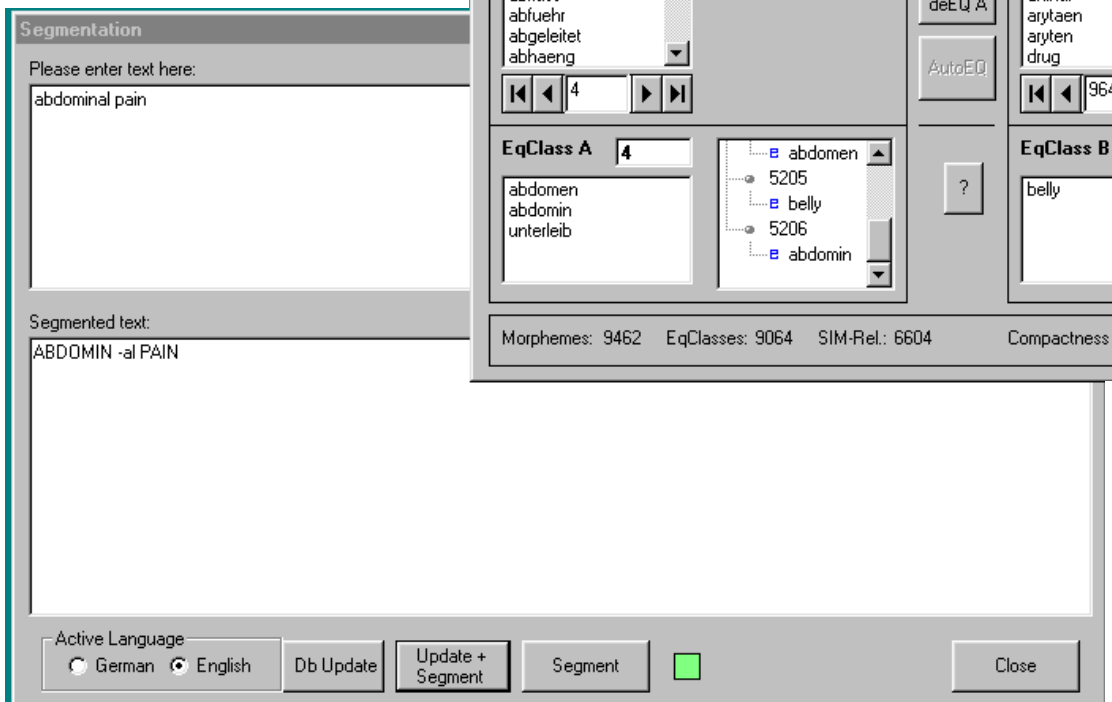
Extended System Architecture



Tool:
Subword Editor & Workbench

editing tool for
subword lexicon
and thesaurus





testbed for
segmentation

The Subword Approach (II)

- Language-specific algorithms for extraction of subwords from (medical) texts
- Multilingual subword repositories
- Criteria for subword delimitation and classification
  - Semantic (compositionality)
    Hyper | *cholesterol* | *emia*
  - Lexical (enabling synonym matching)
    schleimhaut = *mucosa* ~~*(schleim* | *haut)*~~
  - Data-driven (avoiding ambiguities and false segmentation), e.g. relationship, Schwangerschaft (~~relation~~ | ship, ~~Schwanger~~ | schaft)

Disfunção tireoideana perinatal

As doenças da tireóide acometem 10% das mulheres, mas a maioria das pacientes responde bem ao tratamento.

Durante a gestação, mudanças metabólicas podem oculta[illegible] patologia, com risco de dano fetal devido à conduta inapro[illegible] exames de TSH, tiroxina livre e triiodotironina livre são ess[illegible]

Geralmente, a presença de valores elevados de TSH sugere o diagnóstico de hipotireoidismo primário, enquanto níveis suprimidos de TSH sugerem hipertireoidismo. Este último costuma manifestar-se através de bócio, oftalmopatia, fraqueza muscular, taquicardia ou perda de peso.

Original text (D)

Perinatal Thyroid Dysfunction

Thyroid gland diseases affect 10% of women, but most patients respond well to treatment.

[illegible], metabolic changes can hide the presence of the [illegible] risk of fetal damage due to inappropriate handling. [illegible]TSH, free T4 and T3 are indispensable.

Generally, high TSH values suggest the diagnosis of primary hypothyroidism while a suppressed TSH level suggests hyperthyroidism. Typical manifestations of the latter are goiter, ophtalmopathy, muscular weakness, tachycardy, or weight loss

.

DIS FUNCAO TIREOID e ana PERI NATAL

as DOENCA s da TIREOID e ACOMET em 10% das MULHER es MAS a MAIOR ia das PACIENT es RESPOND e BEM ao TRATAMENT o.

DURANTE a GESTAC ao MUDANCA s METABOL ic as[illegible]
ar a PRESENC a da PATOLOG ia COM RISC o de DAN[illegible]
a CONDUT a in APROPRIAD a. os EXAME s de “TSH”,[illegible]
e TRI IODO TIRONIN a LIVR e sao ESSENCI ais
GERAL mente a PRESENC a de VALOR es ELEVAD os de “TSH” SUGER e o DIAGNOST ic o de HIPO TIREOID ism o PRIMAR io ENQUANTO NIVEIS SUPRIM id os de “TSH” SUGER em HIPER TIREOID ism o. este ULTIM o COSTUM a MANIFEST ar se ATRAVES de BOCIO, OFTALM o PATIA FRAQU eza MUSCUL ar TAQUI CARD ia ou PERD a de PESO.

Segmented text

PERI NATAL THYROID DYS FUNCTION

THYROID GLAND DISEAS es AFFECT 10% of WOMEN BUT MOST PATIENT s RESPOND WELL to TREATMENT

[illegible] cy METABOL ic CHANGE s CAN HIDE the [illegible]ISORDER WITH the RISK of FETAL DAMAGE DUE [illegible]e HANDL ing. MEASURE ment of “TSH”, FREE “T4” and “T3” are INDISPENSABLE
GENERAL ly HIGH “TSH” VALUE s SUGGEST the DIAGNOS is of PRIMAR y HYPO THYROID ism WHILE a SUPPRESS ed “TSH” LEVEL SUGGEST s HYPER THYROID ism. TYP ic al MANIFEST ation s of the LATTER are GOITER, OPHTALM o PATHY, MUSCUL ar WEAK ness TACHY CARD y or WEIGHT LOSS.

iiiill iiifunct iiithyr iiiabout iiibirth

iiipatho iiithyr iiiaffect 10% iiifemin iiibut iiihigh iiipatient iirespond iiigood iiitreatment.

iiiduring iiipregnan iiichange iiimetabol iipossibl iii[illegible]
iiiwith iiirisk iiidamage iiifetus iiidue iiibehav iisuita[illegible]
iiihormon, iiithyroxin iiifree iiithree iiijod iiithyronin [illegible]
iiigeneral iipresent iivalue iihigh iithyr iistimul iii[illegible]
iiidiagnos iilow iithyr iifirst iiduring iilevel iisuppress iithyr iistimul iihormon iisuggest iihigh iithyriii. iiilast iicustom iimanifest iiby iigoiter, iiieye iipatho iiweak iimuscle iispeed iiheart iilose iiweigh.

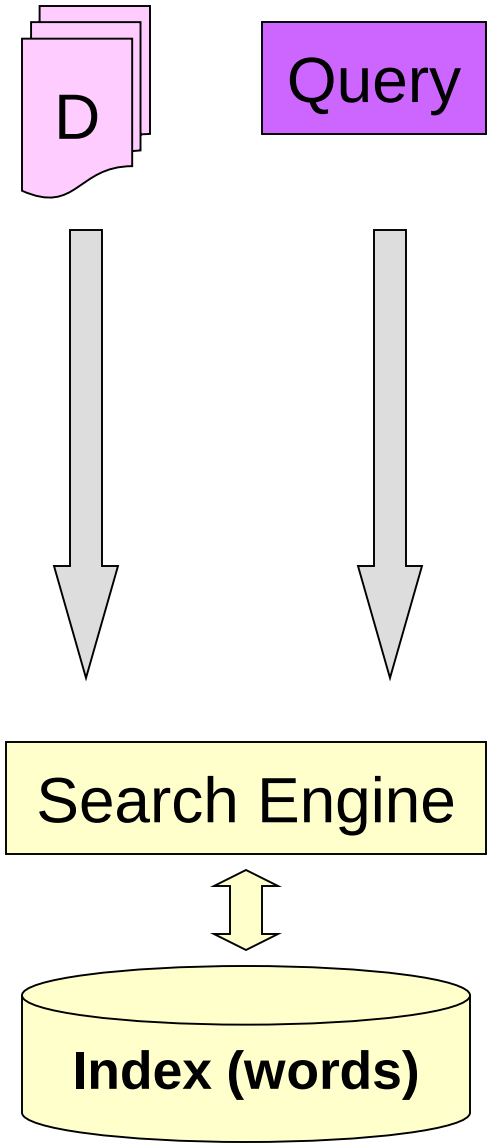
Segmented text mapped to thesaurus Ids (D‘)

iiiabout iiibirth iiithyr iiiill iiifunct

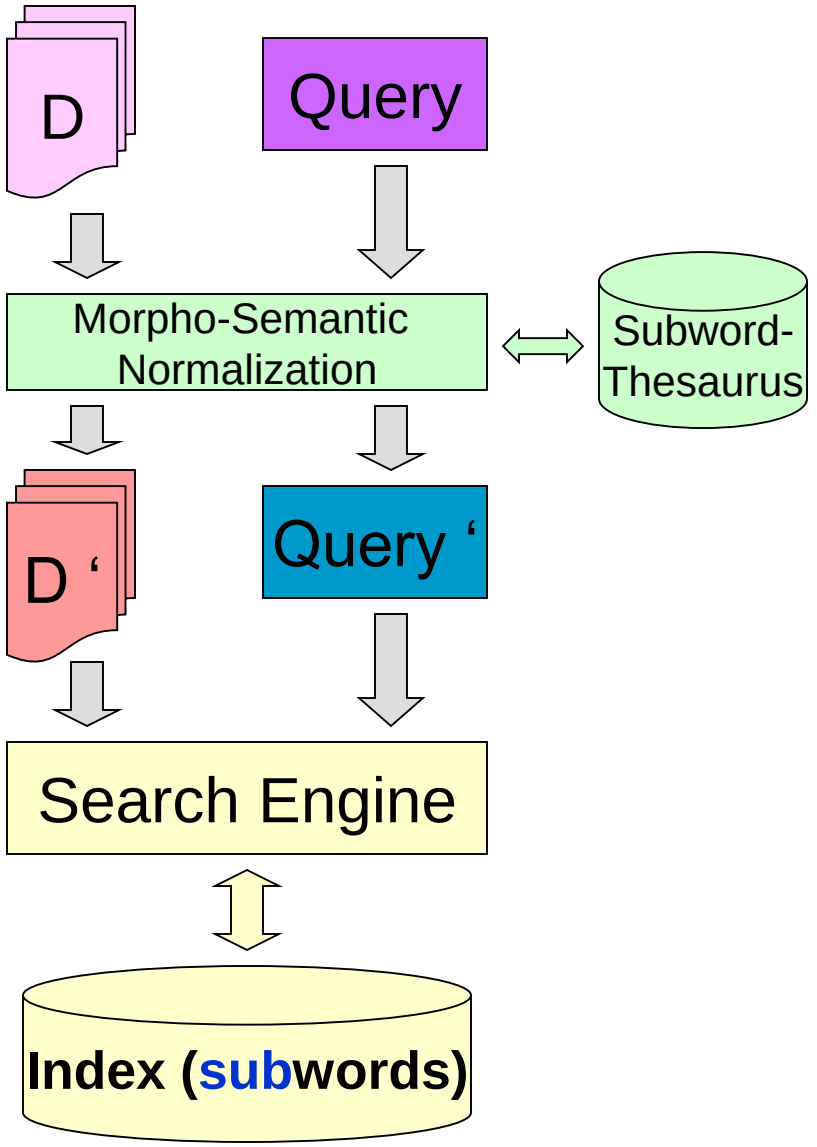
iiithyr iigland iipatho iiiaffect 10% iiifemin iiibut iiihigh iipatient iirespond iiigood iiitreatment

[illegible]ol iichange iican iihide iipresent iipatho iiwith [illegible]ue iisuitabl iimanag. iimeasure iithyr iistimul [illegible] iiithree iijod iithyronin iiessential [illegible]mul iihormon iivalue iisuggest iidiagnos iifirst iilow iithyr iiduring iisuppress iithyr iistimul iihormon iilevel iisuggest iihigh iithyr. iityp iimanifest iilast iigoiteriii, iiieye iipathoiii, iiimuscle iiweak iispeed iiheart iiweigh iilose..

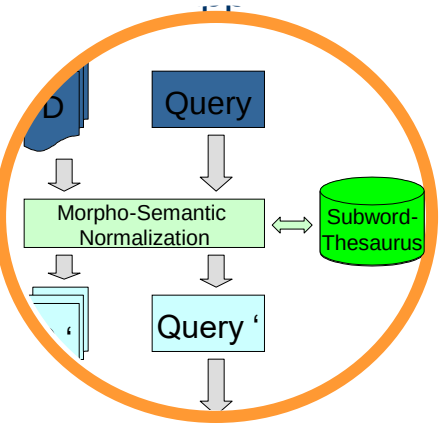
Conventional approach



Subword approach



Lexical Resources



Subword Lexicon:
list of subwords with attributes (type, language, etc.)

{gastr}
{stomach}
{magen}
{ventric}
{chamber}
{hepat}
{hepar}
{liver}
{kidney}
{ren}
{nier}

Equivalence
transitive
and reflexive

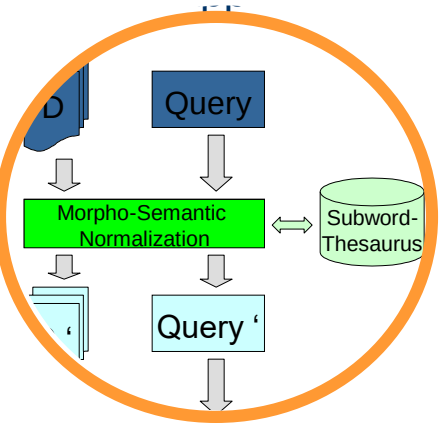
Subword Thesaurus:
groups equivalent subwords, links similar groups

ID#

`ykzyqk`
`jkzyqj`
zyzzjj
xjkkkq
qxkjkq
kkyxkj

Similarity
not transitive,
reflexive

Algorithmic Resources



- Morphosyntactic parser based on a word model described as a finite-state automaton
- Heuristic rules for disambigation of parses