TERMINOLOGY IN INFORMATION EXTRACTION AND TECHNOLOGY FORECASTING

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Funding and Collaboration

• Collaborators at NYU: Zachary Glass, Ralph Grishman, Yifan He, Giancarlo Lee, Shasha Liao, Angus Grieve-Smith and John Ortega

• NYU was a subcontractor of BAE under FUSE
  • FUSE was IARPA’s Foresight and Understanding from Scientific Exposition program
  • Several small projects after FUSE provided additional reasons to extend the system. Some provided additional funding as well.

• Nick Vintilla is creating a distributed processing version of Termolator

• Several other users of the online version have given feedback.
Outline

• What is Terminology?

• 2 Types of Terminology in the FUSE program
  • Term Tokens in Information Extraction
  • Term Types in Technology Forecasting

• NYU’s Terminology Extraction System
  • The Termolator: ☻
  • System and Evaluation
  • Open Source Distribution

• Concluding Remarks
What is Terminology?

- Webster’s II New Collegiate Dictionary Definition
  - The vocabulary of technical terms and usages appropriate to a particular field, subject, science, or art.

- Operational Definitions:
  - Keyword sequences for Information Retrieval (IR)
    - Need not be technical, e.g., wheat, barley, white mouse, in genetics
  - Items to define in Technical Glossaries
  - Items to track for Technology Forecasting (TF)
  - Arguments of Information Extraction (IE) Relations

- Noun Terminology:
  - Technical word sequence headed by noun
  - Vast majority of all terminology
  - Non-noun terminology exists, but not included in this research
The Termolator: 2 Subsystems

- **In-Line Term System**: Finds instances of terms (tokens)
  - Finite State Machine based on dictionaries and POS tags
  - Finds terminology for Information Extraction
  - Identifies term tokens, instances of terms in sentences
    - 500 term tokens occur in document X—50 are instances of *H5N1*
  - Used for Relation Extraction in FUSE
  - Limited previous work in this area

- **Distributional Term System**: Finds term types
  - Counts instances of term types
    - 30 term types occur in document X—*H5N1* occurred 500 times
  - Ranks term types by characteristic-ness to a particular topic
  - Top N term types are kept, the rest are discarded
  - Our FUSE team used term types for Terminology Forecasting
  - Our Distributional Term System Uses In-Line Terms as Input
    - Previous Work: N-grams or Noun-Groups as Input
    - Previous Work used for creating lists of key search terms & glossaries
In-Line Term Tokens are used for IE

- Information Extraction (IE)
  - domain: patents, technical articles, Web of Science abstracts
- Relation arguments are often term tokens
- Entities:
  - Documents (article citations, patents, URLs, standards, self-references like “we” or “our”)
  - People (Inventors, Researchers, etc.)
  - Organizations (Funding Agencies, Patent Holders, …)
  - Term Tokens (topic words, inventions, discoveries, etc.)
- Relations: ABBREVIATE, ORIGINATE, EXEMPLIFY, BASED_ON, CONTRAST, CORROBORATE, BETTER_THAN, PRACTICAL, STANDARD, …
Sample Relations

- **Originate**
  - *Eagle's minimum essential media and DOPG* was obtained from *Avanti Polar Lipids*
    - Originate(*Eagle, Eagle’s minimum essential media*)
    - Originate(*Avanti Polar Lipids, Eagle’s minimum essential media*)
    - Originate(*Avanti Polar Lipids, DOPG*)

- **Contrast**
  - *necrotrophic effector system* that is an exciting contrast to the *biotrophic effector models*
    - Contrast(*necrotrophic effector system, biotrophic effector models*)

- **Better Than**
  - *Bayesian networks* hold a considerable advantage over *pairwise association tests*
    - Better_than(*Bayesian networks, pairwise association tests*)
More Sample Relations

• Significant (sentiment-like, author = implied arg)
  • *Anaerobic SBs are an emerging area of research and development*

• Practical (sentiment-like, author = implied arg)
  • *The gene proteins used in this experiment*

• Alias
  • *Silver behenate, also known as CH3-(CH2)20-COOAg*
Defining In-Line Terms for IE Tasks

- Not all Noun Groups (NGs) can be IE arguments
  - NGs include *table top, large number, first step, other diagram, ...*
  - A narrower classification reduces errors for IE patterns
    - just as selection restrictions reduce attachment errors
- If We Run Distributional System with NGs and use only High-Ranking Terms
  - Too few NGs are considered
  - Many relation arguments will be missed
- IE arguments are a subset of NGs and a superset of high-ranking terms
Our Inline Term Extraction System

• Our POS tagset
  • Refines some PTB POS classes and collapses others
  • Uses dictionaries, word lists and morphological rules
  • Classes include Out-of-Vocabulary Nouns, Technical Adjectives, Person Names, …

• A Finite-State-Machine (FSM)-based chunker identifies potential terms (PTs)
  • Uses B/I/E/O tag sequences in style of (Ramshaw and Marcus 1995) to represent states corresponding to each word W in sentence
  • State(W) depends on: POS(W), POS(W-1) and State(W-1)
    – PT = E v BI* v BI*E

• Filter makes final selection of inline terms
  • Similar well-formedness filter in Distributional System
In-Line Term Extractor

Input Text

A semiconductor device which includes a semi...

Potential Terms
semiconductor device surface stiffener semiconductor chip...

Inline-Terms
semiconductor device semiconductor chip...

FSM Chunker

Filters
FSM Identifies Potential Terms:

- A semiconductor device which includes: a semiconductor chip bonded to a surface of a solid device; and a stiffener surrounding the periphery of the semiconductor chip.

- Differs from standard noun group chunking because some premodifiers are excluded (determiners, some adjectives)
Filters Remove Unlikely Candidate Terms

• Accepts Terms from previous slide which each contain an O-NOUN (Out-of-vocabulary NOUN)
  • semiconductor/O-NOUN device
  • semiconductor/O-NOUN chip (2 instances)
• Also accepts Terms containing technical adjectives or nominalizations
  • thermal/TECH-ADJ stress
  • fabrication/NOM process
• Rejects Terms because they contain no O-NOUNs, technical adjectives, or other qualifying words
  • surface
  • device
  • stiffener
  • periphery
• Other Non-Terms (e.g., morphological properties, status as NE, etc.)
  • T
  • 212-345-8888
  • No.
  • New York
Supplementary patterns for identifying Terms

• Arguments of Abbreviation relations
  • Not organizations or places
  • Aligns words before parentheses with word in parentheses
    • already been chewed (ABC)
    • XML (Extensible Markup Language)
    • third variable loop (V3)
    • D. melanogaster gene Muscle LIM protein at 84B (abbreviated as Mlp84B)
  • Schwartz and Hearst (2003)
• Terms Matching Regexp Patterns
  • Gene Sequences: AACAAGGTGGGCGCAGTT
  • Chemical Formulas: Ag2CrO4
Evaluation of Inline Term System

- 2 Annotators Manually Annotated Inline terms in 3 documents
- Adjudicated the Results
- Scored annotators against adjudicated annotation
- Scored system against adjudicated annotation
- Compared annotator vs system performance
Annotation

• Setup
  • 2 annotators annotated the same three documents
  • Annotator 2 Adjudicated
  • Annotator 1’s score against Adjudicated results may be a good Upper Bound for evaluating the Automatic System (assumes the adjudication is biased in favor of Annotator 2).

• Defining Inline Term for Annotator
  • Single or multi-word nominal expression specific to technical discipline
  • It can be conventionalized by defining or abbreviating it early in the document and by reusing the term
  • Is term specific to technical discipline, i.e., is it obscure enough?
    • Would a naïve adult (like Homer Simpson) know the term?
    • Is it found in the Juvenile subcorpus of the Corpus of Contemporary American English (http://corpus.byu.edu/coca/)?
Corpora and Systems Tested

• Corpora
  • A Speech Recognition Patent (SRC)
  • A Sun Screen Patent (SUP)
  • A Journal Article about a Virus Vaccine (VVA)

• Systems Tested
  • Base 1: assume all noun groups minus determiners are terms
    • use MEMM chunker with Genia (Kim et al 2003) features
  • Base 2: baseline 1 system, but filtered by only keeping those Noun Groups that end with an O-NOUN
  • System without Filter: Chunking system as described, but without the filter
  • Final System

• Matching Criteria
  • Strict Match – The test term and answer key term are the same
  • Sloppy Match – The test term and answer key term overlap in extent.
## Inter Annotator Agreement

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<th>Matches</th>
<th>Pre</th>
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Annotator 1 scores may be upper bounds for system results
## Baseline Systems

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</table>

- Base 1 (all noun groups): results in high recall/low precision
- Base 2 (must end in O-NOUN): too severe a filter.
# System Results

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</table>

Final System gets the highest F-score
Term Types Used in Technology Forecasting

- Technology Forecasting (TF) includes tracking the distribution of instances of the same term
  - A term type is a set of instances of the same term
- A Topic can be represented by a set of term types that “characterize” that topic.
  - Term types with more instances in topic X than in general
- Changes in a topic over time can be indicated by
  - Changes in the set of term types characterizing the topic
  - Changes in the frequency of those term types
- Changes in frequencies of term types in a topic over time
  - Can indicate changes in the “prominence” of these terms
- Approximately the same terms used for: search keys and glossaries (in previous work)
Our Distributional Term System

- Find In-line Terms for Foreground Corpus (or sample)
- Find In-line Terms for Background Corpus (or sample)
- Count instances of the same term
  - Allow for some variation
    - Implemented: (stemming) singular/plural, -ing endings, other
    - Partially Implemented:
      - Abbreviation/full-form
      - Noun mod alternations: Recognition of Speech → Speech Recognition
- Use Statistical Metrics to find terms that are:
  - More characteristic of Foreground than Background
- Rank terms by Metrics
- Rerank terms using additional metrics
  - Relevance Metric, based on a Yahoo Websearch
  - Well-formedness Metric: based on manual rules
- Take Top N terms
A semiconductor device which includes a semi…

A cascade pattern differs from a shower pattern …

Final ReRanked Output: transfer electrode; semiconductor face; micropattern, through-connection, wavelength conversion chip, …
Metrics for Distributional Ranking

- A linear combination of 3 Measures comparing the distribution of terms in the foreground (For) vs background (Bac)

- Term Frequency Inverse Document Frequency (TFIDF)
  \[
  TFIDF(t) = \frac{FreqFor(t)}{FreqBac(t)} \times \log \left( \frac{NumBacDocuments}{NumBacDocsContain(t)} \right)
  \]

- Document Relevance Document Consensus (DRDC)
  - Navigli and Velardi (2004)
  \[
  DRDC(t) = \frac{FreqFor(t)}{FreqBac(t)} \times \sum_{d \in \text{Foreground}} \frac{freq(t,d)}{freqFor(t)} \times \log \left( \frac{freqFor(t)}{freq(t,d)} \right)
  \]
  - Doc Relevance (1st factor) favors representative terms (like TFIDF)
  - Doc Censensus (2nd factor) favors terms found in many documents

- Kullback Leibler Divergence (KLD)
  - Cover and Thomas (1991), Hisamitsu, et. al. (1999)
  \[
  KLD(t) = (\log(freqFor(t)) - \log(freqBac(t))) \times freqFor(t)
  \]
  - Compares Probability of term occurs in Foreground vs. Background
Filters on Distributional Output

- 2 Filters that can be applied to our system or output of other term generation systems
  - In FUSE, they were applied to MITRE and BBN output
- Both scores are between 0 and 1, they are combined by multiplication
- Well-Formedness Filter
  - Many of the constraints are built into our chunker
    - Most terms have a score of 1
  - However, component of distributional System adds some common substrings of terms to output, some of which are ill-formed
- Relevance Filter
  - We use a Yahoo search result and heuristics to score terms more highly if they are used in articles or patents
Well-FormedNess Filter

• A term is well-formed if it is:
  • An abbreviation
  • A set of words that is abbreviated somewhere in the corpus
  • A single out of vocabulary word
  • Matches a regular expression that finds chemical names, DNA sequences or paths (urls, bio paths, etc.) – although URLs can be documents, rather than terms.

• A term is also well formed if it obeys noun group rules (a sequence of adjectives and nouns ending in a noun) AND it contains at least one out-of-vocabulary word, nominalization or technical adjective

• The degree of ill-formedness is not so important as scores below 1 rarely apply to accepted terms.

• This filter is more important when applied to term lists not created by The Termolator (Mitre and BBN term lists in FUSE)
Relevance Filter

- Run on each term below some cutoff (typically 30K)
  - Time consuming (about .75 seconds per term)
- Yahoo search (Bing) for exact match of term
  - Currently use free version
  - Yahoo Api (Boss) would cost .18 cents per search
    • https://developer.yahoo.com/boss/search
- Relevance = H²T
  - H = score representing number of hits
    • \( \min(\log_{10}(\text{numberHits}), 10) \)
    • Minimized to 1 for non-hits (“showing results for” and similar)
  - T = Percent of top 10 hits that are articles or patents
    • Based on key word search in title, url and summary
      - Key words = \{patent, article, proceedings, journal, dissertation, abstract, ...\}
Evaluation of Distributional Term System

- Foreground Corpus: 2500 patents about optical systems
- Background Corpus: 2500 randomly selected patents
- Years: 1997-2007

- Ran the Distributional System and Ordered the Terms
  - Confidence$_1$ = Percentile X Well-Formedness
    - Uses the Percentile Ranking based on the distributional score, but filters out ill-formed terms

- Took the top 30K out of 219K terms and reranked using:
  - Relevance only; and
  - Confidence$_2$ = Percentile X Well-Formedness X Relevance
    - Uses Relevance on 30K terms due to time constraints
Evaluation Distribution System Slide 2

• Took Top 5000 terms ranked each of 3 ways and Scored for Precision
  • Confidence$_1$ Precision = 71%
  • Relevance  Precision = 82%
  • Confidence$_2$ Precision = 86%

• For each ranked set, we took samples of 100 terms:
  • 20 from first 20%, 20 from second 20%, … 20 from 5$^{th}$ 20%.
 • We manually evaluated the samples:
  • Terms were deemed correct if the term was deemed a valid keyword, was not missing any crucial modifier, and did not contain any spurious word.
## Example Evaluations

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<td>.943</td>
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<td>.049</td>
<td>.046</td>
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<td>1685</td>
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<td>.493</td>
<td>1</td>
<td>.067</td>
<td>.033</td>
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<td>3834</td>
<td>panoramagram</td>
<td>.483</td>
<td>1</td>
<td>.056</td>
<td>.027</td>
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<tr>
<td>4203</td>
<td>crystal adjacent</td>
<td>.316</td>
<td>1</td>
<td>.080</td>
<td>.025</td>
<td>No</td>
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<tr>
<td>4244</td>
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<tr>
<td>4467</td>
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<td>.988</td>
<td>1</td>
<td>.024</td>
<td>.024</td>
<td>Yes</td>
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<tr>
<td>4879</td>
<td>photosensitive epoxy resin</td>
<td>.286</td>
<td>1</td>
<td>.079</td>
<td>.022</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Sample Incorrect Terms

• *irradiation time* $t$
  • A variable, not a term (without $t$, it would be a term)

• *evolution*
  • This word has entered the common vocabulary

• *crystal adjacent*
  • This word sequence includes two words at a constituent boundary
    • a noun phrase followed by a modifying adjective phrase, e.g.,
    • [[a liquid crystal] [adjacent to the lower alignment layer]]
Informal Observations about Recall

- Recall or coverage is difficult to measure without an exhaustive amount of human annotation.
- The distributional system gets roughly the same precision for Noun Group input as Inline Term Group Input for the top N terms, where N is a small number.
- Using Inline Terms as input, we generate many more terms with high scores and thus seem to improve Recall by a large amount (at least a factor of 2).
  - But this is hard to measure.
- Rationale: Garbage In → Garbage Out.
  - High F-scores for inline terms (vs NGs or N-grams).
  - Higher Quality terms are being ranked and so the high-ranked items are more likely to be correct.
The Termolator for Chinese

• Work by Yifan He
• Distributional System is the Same as English
• Uses Noun Group Chunker for input terms
• Accessor-Variety Filter (Feng et al., 2004)
  • Score Based on the Number of distinct words that appear before and after a particular term type
  • Low Scores indicate unlikely Chinese words
• 1100 terms extracted from 2000 speech recognition patents
  • 78% precision on top 50 terms
  • 85% precision on top 20 terms
Example of Chinese Term Filtering

- Examples for Access Variety based filtering
  - 含科夫模型 (Markov model, with the first Chinese character 马 missing) is probably a boundary error
  - [Pic on left] 含科夫模型 has the same character 马 on its left boundary thus its Left AV=1
  - [Pic on left] A correct term 声学 (acoustics) will have Left AV>=3
Open Source Distribution

• Open Source release of The Termolator
  - NYU’s Website: http://nlp.cs.nyu.edu/termolator/
  - Github:
    • English: https://github.com/AdamMeyers/The_Termolator
    • Chinese: https://github.com/ivanhe/termolator/

• English system for UTF-8 (including ASCII) & ISO-8859-1
• Tested on Public Domain Texts
  • Google Patents
  • Project Gutenberg
  • Open American National Corpus
Examples from Public Domain Texts

- Gutenberg: Chapters in a Book about knitting vs Other Docs
  - *open-work insertion*, *fine mesh*, *transverse stitching*, *empty scallop*

- Open American National Corpus (OANC) – Biology documents versus random documents
  - *myosin-ii*, *hsn3*, *intron*, *migration defect*, *sparc-null mice*

- Google Patents: Surgery patents (US Patent Class 606) vs Random Patents:
  - *fluid manifold*, *dissector arm*, *pedicle punch*, *balloon catheter*
Future Work: Initial Test in Legal Domain

- Foreground = Roe v Wade Court Opinion
- Background = 64,000 Supreme Court Opinions
- Adaption – Added words from several legal dictionaries to our dictionary
- Top 10 terms in system output (good):
  - medical-legal history, medical abortion practices, common-law prosecutions, roman catholic dogma, good-faith belief, definitional deficiencies, canon-law treatment, historical statutory development, common-law scholar, uniform abortion act
- Terms 21-30 (still mostly good)
  - abortion controversy, canon-law crime, executive assistant attorney, embryo, medical practice act, postconceptive, connecticut birth control law, texas abortion statute, texas to-wit, birth control pill
- Terms 101-110 (OK, but not as topical)
  - texas abortion, sensitive judge, medical advance, childe, abortion patient, gynecologic, therapeutic abortion, extradition provision, governmental invasion
- Terms 401-410 (bad, probably useless)
  - Law-suit, district court hearing, columbia statute, common-law precedent, pseudonym, health department, pasteurizer, pasteur, florida lime, licensure
Our Papers on Terminology & NLP of Technical Literature


Previous Work on Terminology Extraction

• Terms are most typically Noun Groups or Obey Other Linguistic Rules
• Comparing foreground & background documents to rank terms (many others)
• Finding Terminology via Relational Patterns
  • Y. Jin, M. Kan, J. Ng, and X. He. 2013. Mining scientific terms and their definitions: A study of the acl anthology. In *EMNLP-2013.*
Concluding Remarks

• Statistical Comparison of terms in foreground/background is an established method of term extraction.
  • Previous methods use Noun Groups or N-grams as input
• Terminology tokens are often arguments of IE relations
  • Statistical methods cannot find most of these terms
  • Noun Groups produce noisy input for IE
  • Technical NGs, Noun Group-like phrases that include likely technical words (OOV words, technical adjectives, nominalizations, etc.), provide better input for IE
• Using Technical NGs as input to Statistical Term Extraction Results in More High Precision Terms
  • Better input yields more meaningful comparisons (Garbage In, Garbage Out)
• A web-search-based relevance filter improves results
  • Non-Terms are unlikely to be mentioned in technical documents accessed on WWW
• Results:
  • Top In-line Term System: 77.9% sloppy F measure (vs. human ~92% F-measure)
  • Top Distributional Terms System: 86% precision
Extra Slides

- Slides Useful for Providing Extra Examples or Answers to Questions
Customized Parts of Speech 1

• Types of nouns (POS tagger marks NN or NNS)
  • O-NOUN: word is not in our lexicon (Comlex Syntax, lists of person names, lists of specialize vocabulary, e.g., chemical names)
  • PER-NOUN: word begins with a capital letter and is in our dictionary of first and last names
  • PLUR-NOUN: NNS nouns not marked O-NOUN or PER-NOUN
  • NOUN: Other NN nouns

• Types of adjectives (POS tagger marks JJ, JJR, JJS)
  • STAT-ADJ: first word in top ranked term in statistical system
  • TECH-ADJ:
    • adjective ends in -ic, -ous, -ary, and others
    • not in list of exceptions (basic, analagous, voluntary, …)
  • NAT-ADJ
    • adjectival form of country/state/city/continent: European, Indian, Peruvian
  • CAP-ADJ – adjective beginning with a capital letter
Customized Parts of Speech 2

- Verbs:
  - VBG = ING-VERB
  - VBN/VBD = ED-VERB
  - Other verbs are marked OTHER
- POS: possessive marker
- PREP: POS tagger marks TO or IN
- ROM-NUM: I, II, III, IV, …
- Det -- Determiner
- OTHER – all other parts of speech from tagger
Finite State Machine 1

• States
  • S = Start of word sequence
  • B-T = Beginning of Term
  • E-T = End of Term
  • I-T = Inside of Term
  • O = Other

• Transitions to new State is conditioned on:
  • Previous POS
  • Current POS
  • Previous State

• A Possible Term (PT) is:
  • a single E-T
  • B-T + zero or more I-T + zero or one E-T
## Finite State Machine 2

<table>
<thead>
<tr>
<th>Previous POS</th>
<th>Current POS</th>
<th>Previous State</th>
<th>New State</th>
</tr>
</thead>
<tbody>
<tr>
<td>DET, PREP, POSS, OTHER</td>
<td>DET, PREP, POSS, OTHER</td>
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<tr>
<td>O-NOUN, C-NOUN, PLUR-NOUN</td>
<td>ROM-NUM</td>
<td>B-T, I-T</td>
<td>E-T</td>
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<tr>
<td></td>
<td>PLUR-NOUN</td>
<td>B-T, I-T</td>
<td>I-T</td>
</tr>
<tr>
<td></td>
<td>ADJ, CAP-ADJ</td>
<td>I-T</td>
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</tr>
<tr>
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<td>NOUN, PER-NOUN, O-NOUN</td>
<td>B-T, I-T</td>
<td>I-T</td>
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<td>O-NOUN</td>
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<td>I-T</td>
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<tr>
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<td>CAP-ADJ, TECH-ADJ, NAT-ADJ, ING-VERB, ED-VERB, STAT-ADJ, NOUN, O-NOUN, PER-NOUN</td>
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<td>I-T</td>
</tr>
<tr>
<td></td>
<td>Else</td>
<td></td>
<td>O</td>
</tr>
</tbody>
</table>
Term Filter

- Contains at least one noun.
- Is More than 1 character long
- Contains at least one word of all alphabetic characters.
- Does not end in abbrev from list: e.g., cf., etc., …
- No word violating morphological filter, ruling out various ID numbers, patent numbers, etc.
- Does not end in common ending of patent section headings
- Meets at least one of the following Conditions
  - Is a highly ranked topic term
  - Contains a highly ranked topic term
  - Contains at least one O-Noun
  - Is at least 4 words long and contains 3 words that are nominalizations (from NOMLEX) or TECH-ADJ
  - Is a nominalization and is at least 11 characters long
  - Is more than one word long, ends in a common noun and contains a nominalization
- Additional Filters to recognize NEs among PTs