WORKSHOP ON NATURAL LANGUAGE PROCESSING: STATE OF THE ART, FUTURE DIRECTIONS AND APPLICATIONS FOR ENHANCING CLINICAL DECISION MAKING

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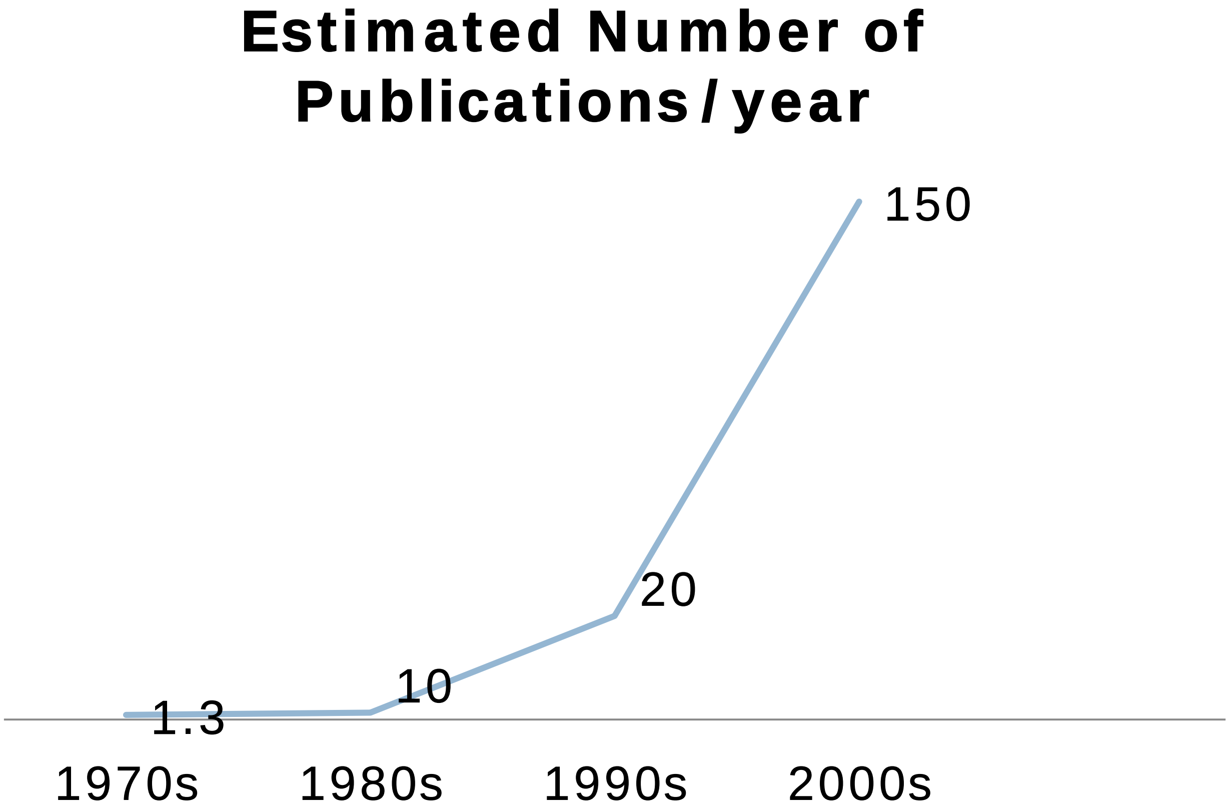
NLP in the Biomedical Domain

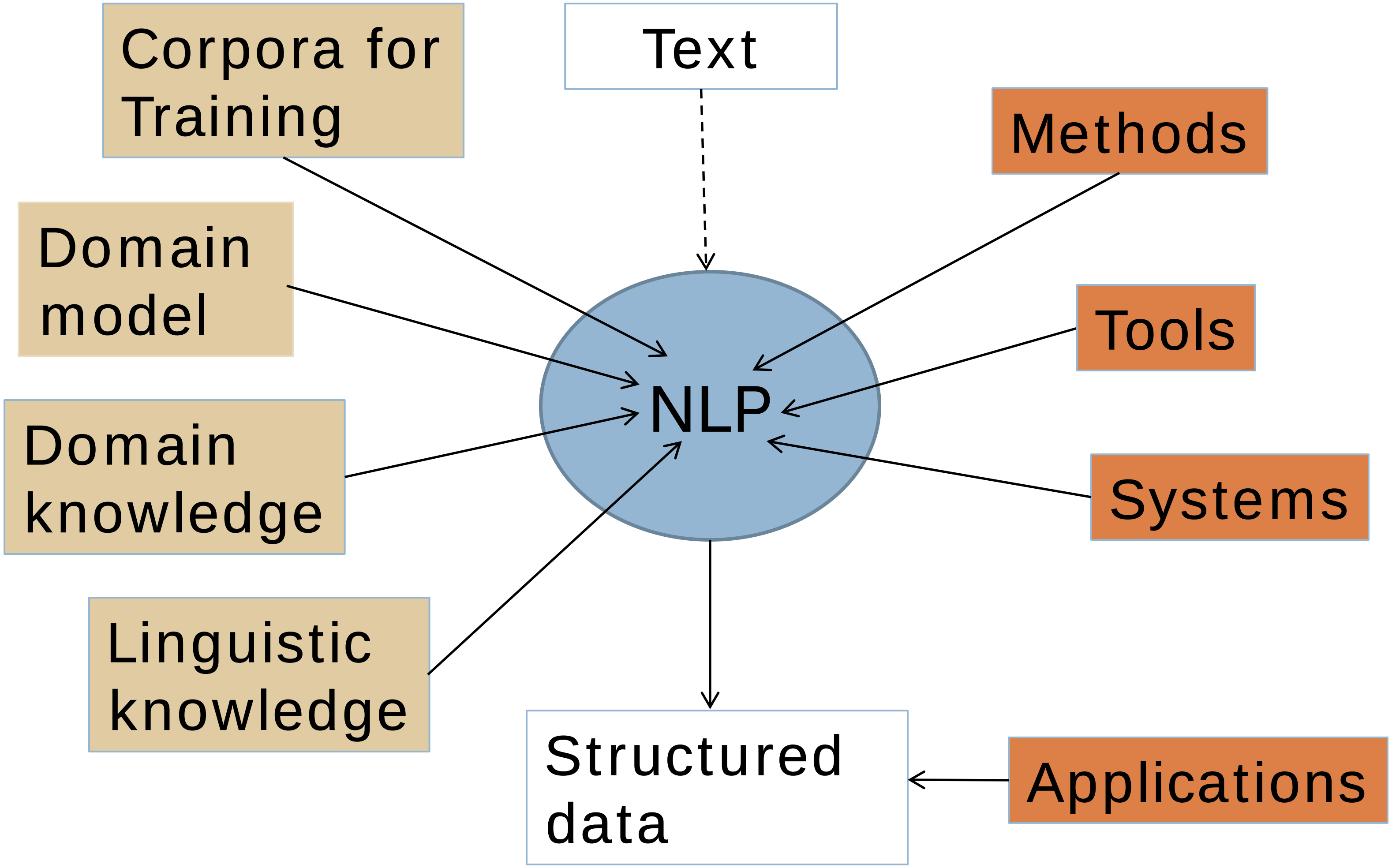


Goal of NLP Workshop

Identify

- Achievements
- Critical challenges
- Recommend future directions

Aspects of NLP



Corpora for Training

Text

Methods

Domain model

Tools

NLP

Domain knowledge

Systems

Linguistic knowledge

Structured data

Applications

Applications: clinical

- Patient care
  - Decision support, quality measures, coding, reduce errors, improve documentation, health information exchange
- Secondary data use
  - Clinical trial recruitment
  - Identify phenotypes
  - Knowledge acquisition and discovery
- Summarization
- Translation
- Tailoring information for consumers
- Computer-generated explanations

Applications: Biomedical

- Improve access to information in text, on Web
- Facilitate curation
- Knowledge acquisition
- Integration of knowledge from multiple sources and disciplines
- Question answering
- Summarization

BioNLP Milestones

- 1960s-70s: Start of clinical NLP
- 1970s, 1980s: Feasibility of structuring clinical information
  - Sager – comprehensive NLP system
- Early 1990s: Demonstration that NLP could be used to improve care
  - Haug (*Symtext*: rule-based syntactic, statistical semantics)
  - Friedman & Hripcsak (*MedLEE*: rule-based semantic/syntactic)

BioNLP: important clinical NLP

- Early-mid 1990s
  - Chute, Elkin: compositionality, terminology, ontology, & NLP
  - Baud, Scherrer, & Rassinoux: ontology-driven semantics, multi-lingual NLP
  - Hahn: Discourse analysis, ontology-based NLP
  - Zweigenbaum: Ontology-driven, semantic analysis of terms

BioNLP Milestones

- Côté RA, Rothwell DJ: SNOMED-standardizing structure of medical language (1980s)
- NLM
  - Lindberg DA, Humphreys BL: UMLS, a critical knowledge source for medical informatics and NLP (late 1980s)
  - McCray: Specialist system: NLP system(early 1990s)
    - McCray, Browne - comprehensive medical lexicon
  - PubMed: Abstracts and MeSH annotations

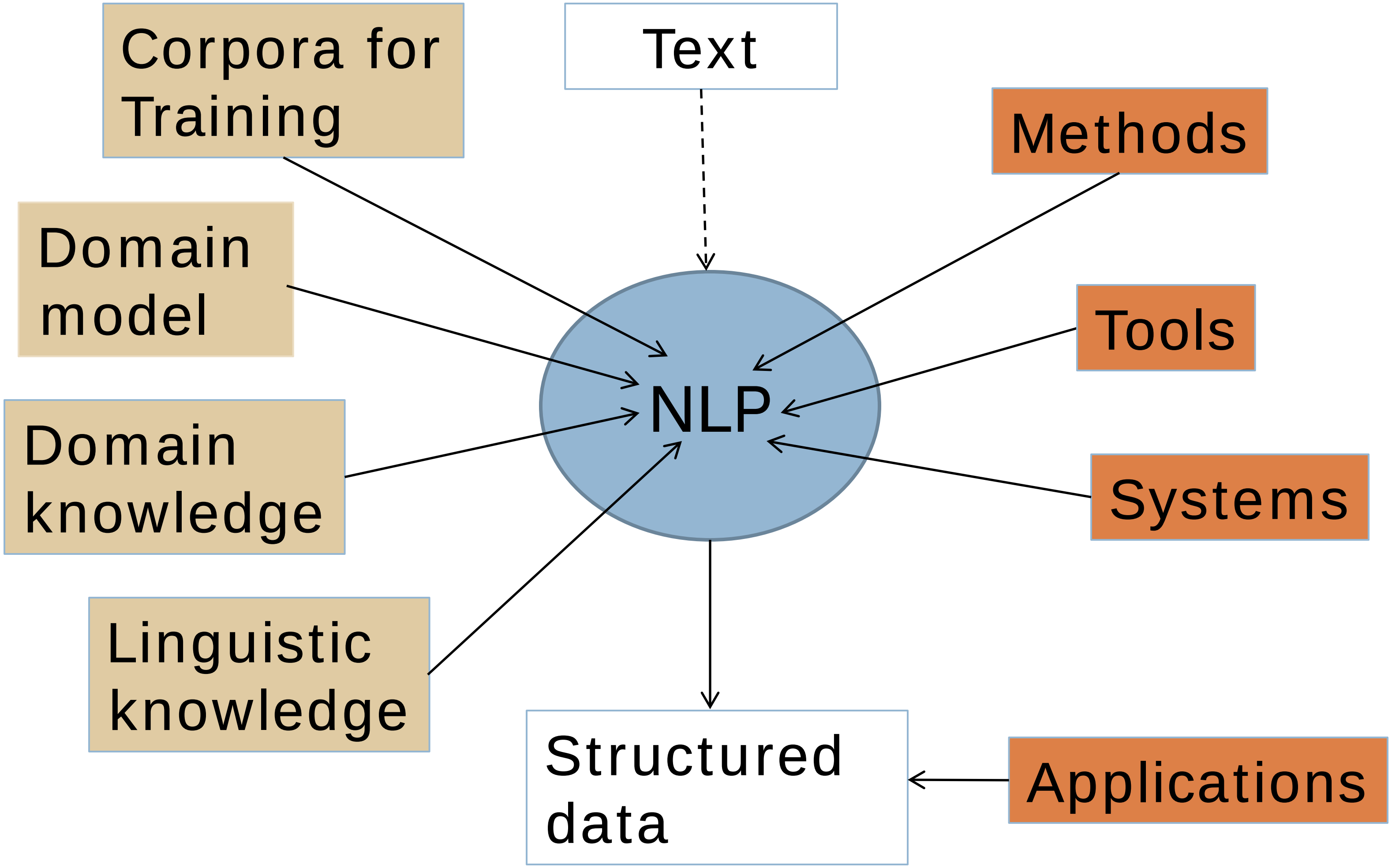
BioNLP Milestones: genomics literature

- NLP in biomolecular domain: named entity recognition, molecular relations, connecting information
  - Late 1990s: Tsujii, Park, Rindflesch, Aronson, Hunter
  - Early 2000s: Rzhetsky, Wong, Raychaudhuri
- Corpora/challenges
  - GENIA corpus: Tsujii
  - BioCreative challenges: Hirschman, Valencia
  - TREC Genomics Track: Hersh
  - BioNLP workshops & challenges

BioNLP Milestones - tools

- MetaMap (Aronson): text to UMLS concepts
- SemRep (Rindflesch): extraction of predications
- Open Source NLP clinical systems
  - NegEx & ConTEXT (Chapman): negation detection expanded to detection of temporality, experiencer
  - caTIES (Crowley): pathology diagnoses
  - cTAKES (Savova, Chute): general information extraction of clinical notes
  - Orbit Project: biomedical informatics tools
    - orbit.nlm.nih.gov

Aspects of NLP



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Applications

General Language Linguistic Knowledge/Tools/Corpora

- Natural Language Tool Kit (NLTK)
  - www.nltk.org
- LingPipe
  - www.alias-i.com/lingpipe
- OpenNLP
  - incubator.apache.org/opennlp
- UIMA
  - uima.apache.org
- Chris Manning's list of resources
  - www-nlp.stanford.edu/links/statnlp.html

Domain Linguistic Knowledge: Lexical

- NLM Resources
  - UMLS Metathesaurus: domain terms
  - UMLS Semantic Network: semantic categories
  - UMLS Specialist NLP tools
  - NCBI resources: biomolecular, species, ...

- OBO (Open Biological and Biomedical Ontologies)

Domain Models

- Critical for interoperability, sharing, and health information exchange
- Models for concepts
- Models for relations

Domain Concept Models

Many domain ontologies/terminologies

- UMLS containing >160 sources
  - MeSH
  - SNOMED
  - RXNORM
  - ICD-9
  - LOINC
- Open Biological and Biomedical Ontologies (gene ontology, cell ontology, chemical, phenotype, disease, ...)

Domain Models of Relations

Clinical domain: represent concepts and their modifiers/qualifiers

- Canon effort
- Galen effort
- Clinical Element Model (Sharp, I2B2, QueryHealth,…)
- http://wiki.siframework.org/

Domain Models of Relations

Biomedical Domain: predicate-argument (PAS) representational models

- Predicates and Arguments with semantic roles
- Models for specific verbs (PASBio, BioProp)
- SemRep predications
  - Based on 26 UMLS relations (causes, disrupts, treats, ...)

Domain Specific Purpose Models

- Representing specific types
  - Guidelines/Clinical Trials
    - EON, GLIF, Arden
- Representing Temporal Data
  - TimeML
  - Temporal constraint structure

Annotated Domain Corpora: Biomedical Literature

- PubMed – MeSH
- GENIA – semantic, syntactic, entities, relations
- BioCreAtIvE: annotated for realistic tasks
  - gene, protein mentions/ normalization/molecular interactions/cross-species
- PASBio,BioProp: predicate-arguments for specific verbs
- BioScope, BioInfer: negation, uncertainty & scope (some clinical)
- WSD, MSH WSD test collections: annotations of 50 & 203 ambiguous terms

Domain Corpora: Raw Clinical Documents

- Cincinnati Children’s Hospital
  - De-identified pediatric corpus
- Pittsburgh
  - De-identified reports from multiple hospitals
- MIMIC
  - Longitudinal de-identified reports
    - 26,000 patients in ICU setting
    - > 1 million notes
    - Discharge summaries, ECG/echo/radiology reports, and doctor and nursing notes
    - ICD-9 codes

Domain Corpora: Annotated Clinical Documents

- Cincinnati’s Children Hospital
  - Radiology reports: ICD-9 coding annotations
- I2B2 Challenges (2007-2012)
  - De-identified discharge summaries: annotated for various challenges
- TREC Medical Records Track

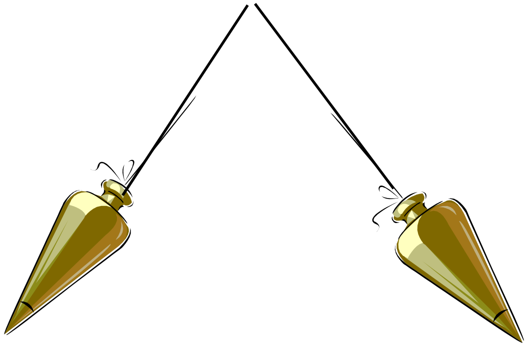
Challenges & Future Directions

Issues/Future Directions

- Access to more clinical notes & larger variety
- New methods vs. incremental methods
- More varied applications
- Evaluation
  - Important to learn from results
  - Some tasks more difficult than others: Why?
    - General vs. specific task
    - NLP issues vs. other reason
    - Domain reasoning

Issues/Future Directions: Linguistic Trends

Empirical corpus-based (before late 1950s)



Manual rule-based, linguistic-expertise (late 1950-late 1980s)

Statistical corpus-based (late 1980s–present)

Issues/Future Directions: Development of hybrid methods

Advantages of statistical methods

- Automated detection of textual patterns possible
- Many machine learning (ML) tools available
- Annotation & tools enable
  - Rapid implementation
  - Implementation without linguistic expertise
- Easy to experiment with different features, ML methods

Issues/Future Directions: Development of hybrid methods

Some disadvantages also

- Annotation is costly
- Performance depends on having similar corpora
- Statistical patterns are not intuitive
- Error analysis difficult to perform
- Errors cannot be rapidly fixed
  - Requires more annotated text or
  - Changes in method

Issues/Future Directions: Development of hybrid methods

Need synergistic models

- Methods that integrate
  - Expert rules
  - Domain knowledge
  - Machine learning
- Methods that allow experts to overrule
- More linguistically intuitive

Issues/Future Directions: Lexical knowledge in clinical domain

Identifying senses of abbreviations clinicians use

- Not defined in reports, often contain 2-3 letters
- Typical
  - Ca (*cancer*, *calcium* as measurement, *calcium* as medication)
  - PD (*Parkinson disease*, *primary care physician, peritoneal dialysis, pancreatic duct*)
- Atypical
  - HF
  - RH
  - b4

Issues/Future Directions: Word sense disambiguation

- Critical and difficult problem
- Large number of ambiguous words
- Performance varies for individual ambiguous words
  - Local vs. global vs. contextual vs. knowledge-based features

Issues/Future Directions: Domain Models

- Continue representational modeling work
  - Include rich features that affect meaning/use
  - Expand predicate-argument relations in clinical domain
  - Evaluate models for accuracy & coverage based on real text

Future Directions: Balance & Broaden NLP research portfolio

- Improve data entry
  - Reduce use of abbreviations
  - Reduce cut/paste
  - Improve template creation and use
- Improve EHR documentation
- Develop cutting-edge applications
- Summarization
- Question-answering
- Improve access to information for consumers
- Knowledge acquisition, integration, and discovery

Issues/Future Direction

Keep up the momentum!