Natural Language Processing in the Medical and Biological Domains : a Parallel Perspective

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Natural Language Processing in the Medical and Biological Domains : *Why are they different ?*

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Introduction

Natural language processing in two related domains

- Are they more or less the same ?
- Do the observed differences come from the two domain topics ?
- Must other origins be called for (tasks, etc.) ?

Natural Language Processing in the *Medical* Domain

Natural Language Non-artificial language used by humans

Natural Language Processing (NLP) Computer processing (analysis, generation, etc.) of natural language utterances

Medical Domain That of *Medical Informatics*:

- Health care (treat patients)
- Associated information and knowledge management (medico-economic goals, best practice)
- Acquiring new knowledge (medical research)

Natural Language Processing in the *Biomedical* Domain

Natural Language Processing As in the medical domain

Note : Text Mining

- Data mining from text [Hearst, 2003]
- Beyond simple information extraction : synthesis, hidden links, new knowledge
- Generally relies on Natural Language Processing

Biomedical Domain That of *Biomedical Informatics* :

- Molecular Biology
- Genomics
- *omics

1. Observations
    - MEDLINE View
    - Outline of Medical NLP Work
    - Outline of Biomedical NLP Work
2. Two Domains
    - Clinical Sublanguage
    - Biomolecular Sublanguage
3. User Needs and Tasks
    - Medical NLP : Diverse User Needs
    - Biomedical NLP : More Focused User Needs
4. Impact of Text Genres
    - Open Access
    - Language
5. Attractivity Factors
6. Wrap-up

Medical and Biomedical NLP

According to MEDLINE

1. “Natural Language Processing” [Main Heading]
   - MeSH record : *91(87) ; was see under ARTIFICIAL INTELLIGENCE 1987-90*
2. Genome biology : union of numerous descriptors
   - Used simple approximating expression of [Demner-Fushman et al., 2007] :

```
("genes"[TIAB] NOT Medline[SB])
 OR "genes"[MeSH Terms] OR gene[Text Word]
 OR "genetics"[Subheading]
```

Approximation of BioNLP : 1 & 2

- Manual check
- Also examine “text mining”[all fields]

Medical and Biomedical NLP in MEDLINE

Discussion

- See also [Rebholz-Schuhman et al., 2007]
  - 1990-1999 *vs* 2000-2005 in Medical Informatics and Biomedical Informatics
  - Frequent bigrams reveal common apparition of *ontology*, *text mining*, *SVM*
  - Here, focus on NLP + much simpler study
- Search biases :
  - MEDLINE does not contain all Bio/Medical/NLP publications
  - Search expressions roughly approximate actual goal

Medical and Biomedical NLP in MEDLINE

Boundaries and quantities

prehistory	NLP[mh]	NLP & <gene>	"text mining"
< 1983	1983–2008.08	1999–2008.08	1999–2008.08
0	1263	265	244

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- Earliest NLP in MEDLINE :
  - Chi EC, Sager N, Tick LJ, Lyman MS (1983) Relational data base modelling of free-text medical narrative, *Med Inform (London)*
  - Gabrieli ER, Speth DJ (1986) Automated analysis of the discharge summary, *J Clin Comput*

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- Earliest NLP & <gene> in MEDLINE :
  - Rindflesch TC, Hunter L, Aronson AR (1999) Mining molecular binding terminology from biomedical text, *Proc AMIA Symp*
  - Rzhetsky A, Koike T, Kalachikov S et al. (2000) A knowledge model for analysis and simulation of regulatory networks, *Bioinformatics*

Medical and Biomedical NLP in MEDLINE

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- Early Text mining in MEDLINE :
  - Tanabe L, Scherf U, Smith LH, Lee JK, Hunter L, Weinstein JN (1999) MedMiner : an Internet text-mining tool for biomedical information, with application to gene expression profiling. Biotechniques

Medical and Biomedical NLP in MEDLINE

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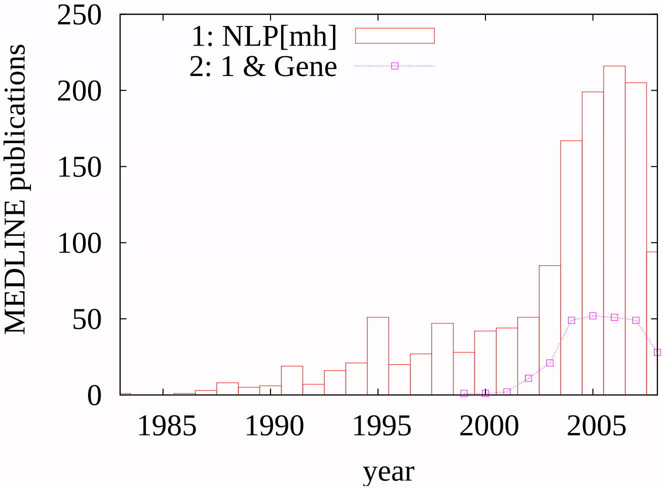
- Who uses “text mining” ($n = 244$) ?
  - Text mining & NLP = 89/244 (36%) :
    - Text mining does not imply NLP ?
  - Text mining & <gene> = 139/244 (57%)
  - Text mining & biomedical (manual) = 196/244 (80%) :
    - Text mining ⇒ BioNLP

Medical and Biomedical NLP in MEDLINE

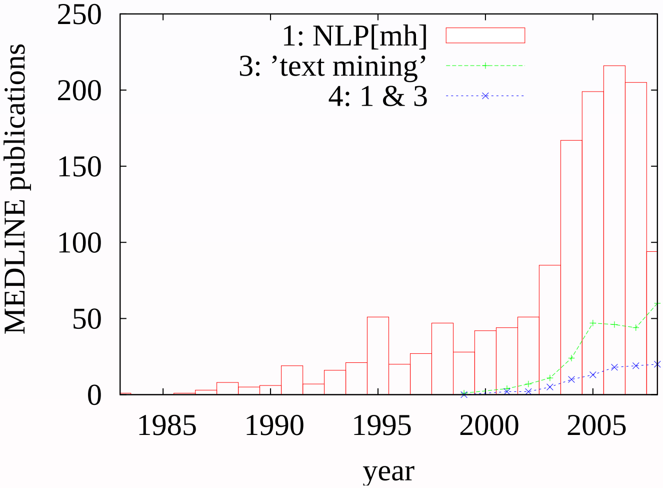
Along the years : NLP[mh] & <gene>



Hand-check : in 2007, 82 papers/185 are biomedical NLP

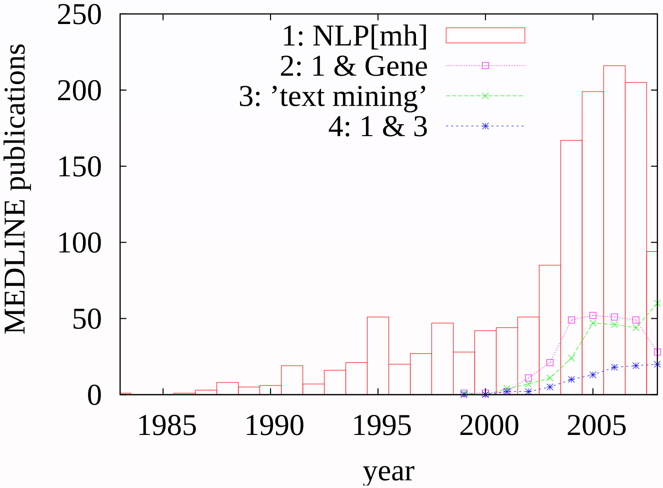
Medical and Biomedical NLP in MEDLINE

Along the years : NLP[mh] & “text mining”



Medical and Biomedical NLP in MEDLINE

Along the years



Outline of Medical NLP Work

A constellation of activities

Medical NLP : Community

IMIA WG 6 1981- Coding, Medical concept representation, NLP

- Triennial workshop (1981-)

AMIA NLP SIG/WG 19 ? ? then 2000- Natural language processing

- Started the first ACL workshop
  "Natural Language Processing in the Biomedical Domain" (2002)
- A growing proportion of sessions at the AMIA Symposium :
  - NLP, Text mining, links to Terminology and Ontology

EFMI WG NLU 2002 ?- Natural language understanding

Medical NLP : Lexical Resources

- UMLS Specialist Lexicon
- UMLS Specialist Lexical tools
- + Scattered resources in various teams

Strong link with terminology development and maintenance (coding)

Medical Ontologies

Principled ontology design ; issues important in medical domain (mereology, non-existence, uncertainty. . .)

- GALEN
- SNOMED CT
- Foundational Model of Anatomy

Role of IMIA WG 6

Medical NLP : Named Entity Recognition

- Mostly viewed through coding and indexing
- More Automated Term Recognition than really NER
    - Includes term/concept normalization
- MetaMap [Aronson, 2001]

Medical NLP : Indexing and IR

- MeSH, MEDLINE : SAPHIRE [Hersh], MTI [Aronson et al., 2000]
- SNOMED, ICD : numerous works
- UMLS : MetaMap
- Concept-based indexing

Medical NLP : Semantic Analysers

- LSP-MLP : clinical, literature [Sager et al., 1987]
- MedLEE : clinical [Friedman et al., 1994]
- SemRep : literature (mostly) [Rindflesch]
- ...

Medical Text Mining

Literature-based discovery

A large proportion of works in Literature-based discovery target medical relations

- Swanson & Smalheiser : Arrowsmith (disease, substance) `http://arrowsmith.psych.uic.edu/cgibin/arrowsmith_uic/start.cgi`
- Hristovski et al. : BITOLA (disease, substance, drug) — maybe_treats `http://www.mf.uni-lj.si/bitola/`
- etc.

Outline of Biomedical NLP Work

A culture of “community collaboration”

Biomedical NLP : Community

- ISMB BioLINK SIG on Text Data Mining
- Mailing lists : BioNLP (2001), ISMB BioLINK
- Workshops
  - BioLINK (2001-), BioNLP, SMBM, LBM. . .
- ACL SIG BioMed (2008)

Biomedical NLP : Lexical Resources

- Issue of recognition of genes/proteins, etc., and their variants
- Large lists of names extracted from reference databases
- Unification initiatives (BioLexicon [Sasaki et al. SMBM 2008])

Biomedical NLP : Ontologies

Active development

- Gene Ontology (GO)
- Gene Regulation Ontology
- Repository, unification : Open Biomedical Ontologies (OBO)

Kim/Rebholz-Schuhmann, SMBM Tutorial, 1/9/2008

Biomedical NLP : Annotated corpora

`http://compbio.uchsc.edu/ccp/corpora/obtaining.shtml`

`http://mars.cs.utu.fi/PPICorpora/`

Corpus	Sentences
LLL (train)	77
HPRD50	145
PDG/PICorpus	283
IEPA	486
BioCreative-PPI (BC I)	1000
BioInfer	1100
AIMed	1955
GENIA	18546/9372 (term/event)
Genetag	20000
ITI TXM (PPI)	75000 (upcoming)

Biomedical NLP : Shared Tools

Example : repositories of UIMA Components

- JCoRe (JULIE Lab, U Jena)
- Tsujii Lab UIMA repository (U Tokyo)
- ClearTK (U Colorado)
- Mayo Clinic (upcoming)
- BioNLP-UIMA Component Repository
- U-Compare (Upcoming ; Tsujii lab, U Colorado, NaCTeM)

Tomanek/buyko/Goetz, SMBM Tutorial, 1/9/2008

Biomedical NLP : Challenges

Organization of shared tasks

- KDD Cup 2002
- TREC Genomics 2003–2007
- JNLPBA 2004
- LLL 2005
- AIMed 2005
- BioCreative I (2004) & II (2006)

Biomedical Text Mining

Literature-based discovery

- Strong interest for Biomedical LBD

Biomedical NLP : Wider Attraction of External Researchers

External to Bioinformatics

- Data mining
  - KDD Cup
- Computational linguistics
  - Workshops at ACL conferences
- Machine learning
  - LLL Challenge

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Two sublanguages

Sublanguage Subset of language within a specialized domain that exhibits specialized constraints due to limitations of the words and relations of the subject matter
(Z. Harris, cited in Friedman et al. [2002])

- Particular word classes
- Particular statement types

A comparison of features of two sublanguages

[Friedman et al., 2002]

- Clinical domain
- Biomolecular domain

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Clinical Sublanguage : Entities

- Descriptions of *entities* and *events* associated with the *patient state*
- Primary concepts
  - disease, procedure, medication, vital sign, symptom, body location
  - mostly nouns
  - modifiers are generally adjectives or nouns

Clinical Sublanguage : Relations

- Simple relations
  - single finding + modifiers
  - verbs are frequently omitted : [*patient had*]
  - *fever and headache* ; *heart was enlarged* ; *pulse measured 70 bpm*
- Complex relations
  - connect findings to (findings | procedures | treatments)
  - with conjunctions (*and*, *with*),
  - prepositions and verbs associated to causality (*due to*, *led to*), etc.

Biomolecular Sublanguage : Entities

- Descriptions of *events* associated with *biomolecular substances* and their *interactions*
- Primary concepts
  - gene, protein, aminoacid... cell, structure, tissue, species
    - creative names*
  - descriptions of biomolecular pathways
    - process, pathway, disease
    - complex interactions and other relations
    - activate, inactivate, attach... signal, substitute, transcribe

Biomolecular Sublanguage : Relations

- Primary relations
  - expressed using verbs of interaction (*p53 binds to il2*)
  - frequently, nominalisations (*activation*) to allow for nesting
- Sequences of interactions
  - highly nested relations
  - *Inhibition of 4 e-bp1 phosphorylation enhanced 4 e-bp1 binding to eif-4e*

```
[action,promote,
    [action,inactivate,x,
        [action,phosphorylate,x,[protein,4 e-bp1]]],
    [action,attach,[protein,4 e-bp1],[protein,eif-4e]]]
```

Two Sublanguages : Summary

Clinical	Biomolecular
Patient reports	Scientific literature
Descriptive	Complex relations between biomolecular substances
Nouns and adjectives	Relations based on verbs

Some overlap

- Tissues, cells, molecular components (markers in pathological reports)
- Diseases (in association with biomolecular interactions)

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Medical NLP User Needs

Those addressed by Medical NLP researchers

- Hospital
  - Patient records : coding and information extraction
  - Decision support :
    - [cf Patient records]
    - knowledge extraction (e.g. from guidelines)
    - literature search (e.g. InfoButtons)
  - Terminology management
- Research
  - Literature search : indexing, information retrieval etc.
  - Hypothesis testing : literature-based discovery

Biomedical NLP User Needs

Those addressed by Biomedical NLP researchers

- Literature search : indexing, information retrieval and co.
- Curation (building databases) : coding and information extraction
- Hypothesis testing : literature-based discovery

Facilitating Factors

More focused user needs

Less diverse tasks

Shared tasks

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Genres of Input Texts

	Medical	Biomedical
Clinical reports	√	
Terms	√	√
Guidelines	√	
Outbreak reports	√	
Scientific literature	√	√

Different genres of texts induce different constraints

Clinical Reports : Privacy

Requirement : Protection of privacy

Solution : De-identification

- Additional, necessary effort to enable shared research
- Strong limitations on corpus sharing
- CMC ICD9-CM coding challenge
- i2b2 challenges
- Upcoming effort of AMIA NLP WG

The requirement for privacy protection

imposes a burden on Medical NLP research

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Scientific Literature : Open Access

- Catalogue
  - 1997 : MEDLINE access becomes free
- Journals
  - 1997 : PNAS Online
  - 1997 : Mol Biol Cell Online
  - 1998 : BioMed Central
  - 2000 : PLoS (2003 : PLoS Biology)
- Repositories
  - 2000 : Pubmed Central
- Access is still limited for some full-text articles

Open access to the scientific literature

fosters Biomedical NLP research [Bourne et al., 2008]

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Clinical Reports : Local Languages

Requirement for localisation

Clinical reports must be written in the language of the user

- Doctors write/dictate/read in their own language
- Patients must be able to understand the contents of their files

Clinical Reports : Local Languages

Necessary effort to develop resources for each natural language

- Lexicon
- Morphology
- Terminology
- [Ontology]
- . . .

- POS-tagger
- NER
- Parser
- Relation patterns
- Coreference

Clinical Reports : Local Languages

- A large number of projects have made parallel efforts in different languages
  - German, French, Dutch. . .
- Few coordinated efforts to organize this diversity
  - FP3 MENELAS (1992–1995)
    Analysis of discharge summaries in French, English, Dutch
  - NoE Semantic Interoperability and Data Mining in Biomedicine : WP20, Multilingual medical dictionary
- English is an exception : NLM–UMLS

The multiplicity of local languages

leads to a dispersion of concrete efforts in Medical NLP

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Scientific Literature : One Language

One biomedical language

- Most international scientific literature is written in (scientific) English
- Language of experimental science

Scientific Literature : One Language

The unicity of language

simplifies sharing of resources in Biomedical NLP research

[See above]

- Lexicon
- Morphology
- Terminology
- [Ontology]
- . . .

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Scientific Literature : One Language

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[See above]

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Scientific Literature : One Text Genre

- Scientific article in experimental science
- Actually, differentiate
  - Abstract
    - Structured abstract
  - Full-text paper
    - Various structures

The unicity of text genre

simplifies the construction of text corpora

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A Conjunction of Enabling Factors

Single type of text

Public access to input texts

Single language

Shared corpora

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Intrinsic Attractivity of Genomics

- Help health information processing
  - Health-related issues : a good deed
  - Much medico-economic motivation though
- Help biomedical research
  - Scientifically appealing
  - Promise of more fundamental outcomes
  - Scientific discoveries

Funding

Funding for research in medical information processing

- Fluctuations over the years

Funding for biomedical research

- Sustained level of funding since genome sequencing

Resources

A variety of shared resources

- Input text collections
- Lexical, terminological, ontological resources
- NLP/IE tools

facilitates entry of new players

- Bioinformaticians
- [General] computational linguistics researchers
- Machine learning researchers
- Industry

Annotated Corpora

Most crucial to progress in the field are annotated corpora

- Analysis
- Evaluation
- Training
  - Enables the use of machine learning methods

This is possible thanks to

- Open access
- One language
- Defined, common tasks

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Challenges

A driving force in all domains—when possible

- Focus efforts
- Enable comparison of [methods and] systems
- Co-operative definition of tasks
- Comparative evaluation
- Clearly defined framework

Depend on tasks and corpora

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Wrap-up : Biomedical *vs* Medical NLP

Less diverse tasks

More focused user needs

Single type of text

Public access to input texts

Single language

Shared tasks

Shared corpora

Machine learning

Challenges

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