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Language Technology: Research and Development

Language Technology Research and Development

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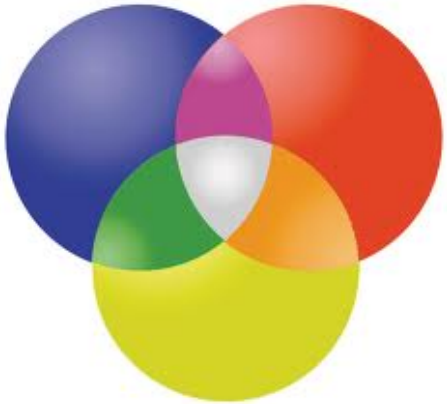
The Name of the Game



Computational Linguistics (CL)

Natural Language Processing (NLP)

[Human] Language Technology ([H]LT)

[Natural] Language Engineering ([N]LE)

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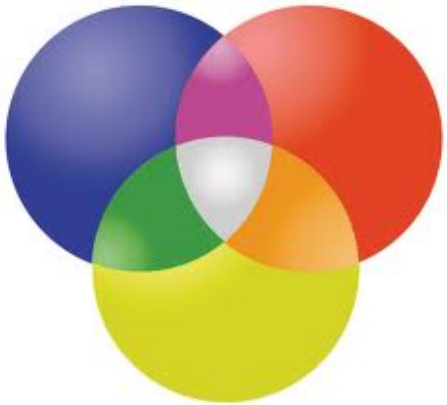

Computational Linguistics (CL)

- Study of natural language from a computational perspective

Natural Language Processing (NLP)

- Study of computational models for processing natural language

[Human] Language Technology ([H]LT)

- Development and evaluation of applications based on CL/NLP

[Natural] Language Engineering ([N]LE)

- Same as [H]LT but obsolete?

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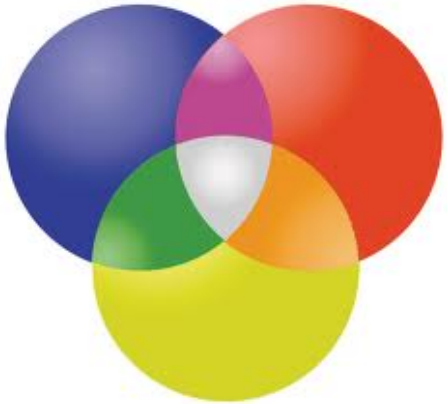


Computational Linguistics (CL)

Natural Language P[illegible] (N[illegible])

Often used more or less synonymously!

[Human] Language [illegible]

[Natural] Language Engineering ([N]LE)

An Interdisciplinary Field

Linguistics

- Theory, language description, data analysis (annotation)

Computer science

- Theory, data models, algorithms, software technology

Mathematics

- Theory, abstract models, analytic and numerical methods

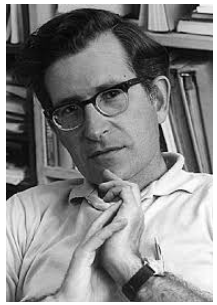
Statistics

- Theory, statistical learning and inference, data analysis

Linguistics

F. de Saussure
(1857–1913)

L. Bloomfield
(1887–1949)



N. Chomsky
(1928–)

- Structuralist linguistics (1915–1960)
  - Language as a network of relations (phonology, morphology)
  - Inductive discovery procedures
- Generative grammar (1960–)
  - Language as a generative system (syntax)
  - Deductive formal systems (formal language theory)
  - NLP systems based on linguistic theories

Linguistics

- Recent trends (1990–):
  - Language processing (psycholinguistics, neurolinguistics)
  - Strong empiricist movement (corpus linguistics)
  - NLP systems based on linguistically annotated data
- Theoretical and computational linguistics have diverged

  Interaction between Linguistics and Computational Linguistics: Virtuous, Vicious or Vacuous? (Workshop at EACL 2009)

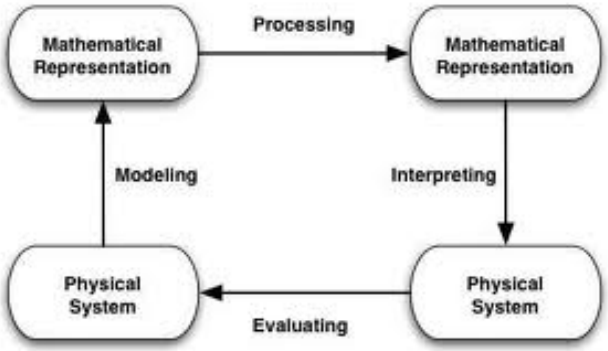
Computer Science

Alan Turing
(1912–1954)

Herbert Simon and John Newell
(1916–2001) (1927–1992)

- Theoretical computer science
  - Turing machines and computability (Church-Turing thesis)
  - Algorithm and complexity theory (cf. formal language theory)
- Artificial Intelligence
  - Early work on symbolic logic-based systems (GOFAI)
  - Trend towards machine learning and sub-symbolic systems
  - Parallel development in natural language processing

Mathematics



- Mathematical model
  - Description of real-world system using mathematical concepts
  - Formed by abstraction over real-world system
  - Provide computable solutions to problems
  - Solutions interpreted and evaluated in the real world
- Mathematical modeling fundamental to (many) science(s)

Mathematics

- Real-world language technology problem:
  - Syntactic parsing: sentence $\Rightarrow$ syntactic structure
  - No precise definition of relation from inputs to outputs
  - At best annotated data samples (treebanks)
- Mathematical model:
  - Probabilistic context-free grammar G

$$T^* = \underset{T:yield(S)=T}{\text{argmax}} \; P_G(T)$$

  - T^* can be computed exactly in the model
  - T^* may or may not give a solution to the real problem
- How do we determine whether a model is good or bad?

Statistics

Probability theory

- Mathematical theory of uncertainty

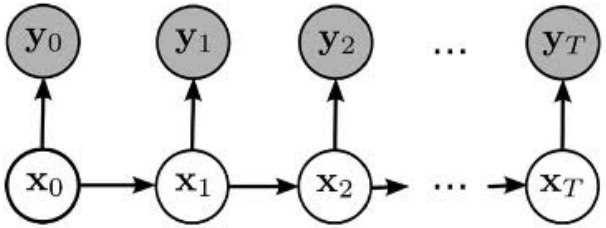
Descriptive statistics

- Methods for summarizing information in large data sets

Statistical inference

- Methods for generalizing from samples to populations

Statistics



- Probability theory
  - Framework for mathematical modeling
  - Standard models: HMM, PCFG, Naive Bayes
- Descriptive statistics
  - Summary statistics in exploratory empirical studies
  - Evaluation metrics in experiments (accuracy, precision, recall)
- Statistical inference
  - Estimation of model parameters (machine learning)
  - Hypothesis testing about systems (evaluation)

Language Technology R&D

Sections in Transactions of the ACL (TACL):

- Theoretical research
- Empirical research
- Applications and tools
- Resources and evaluation

Language Technology R&D

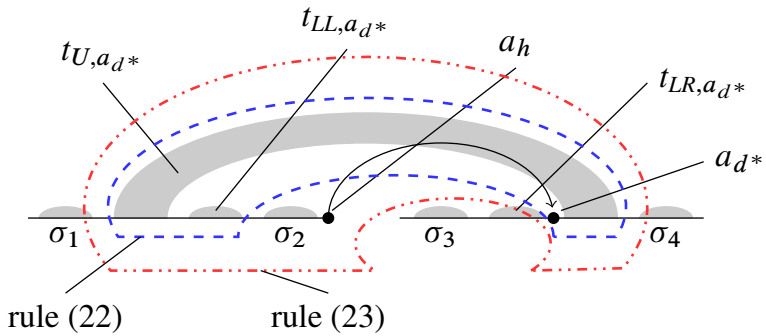
Sections in Transactions of the ACL (TACL):

- Theoretical research – deductive approach
- Empirical research – inductive approach
- Applications and tools – design and construction
- Resources and evaluation – data and method

Theoretical Research

- Formal theories of language and computation
- Studies of models and algorithms in themselves
- Claims justified by formal argument (deductive proofs)
- Often implicit relation to real-world problems and data

Theoretical Research



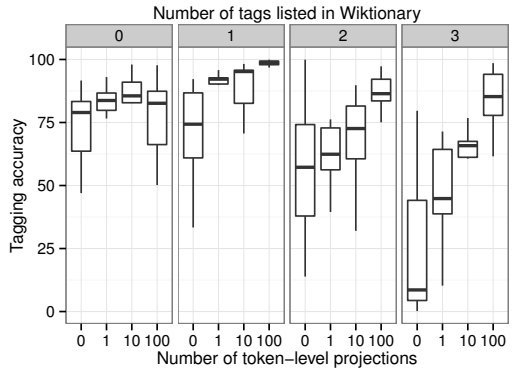
Satta, G. and Kuhlmann, M. (2013)
Efficient Parsing for Head-Split Dependency Trees.
Transactions of the Association for Computational Linguistics 1, 267–278.

- Contribution:
  - Parsing algorithms for non-projective deendency trees
  - Added constraints reduce complexity from $O(n^7)$ to $O(n^5)$
- Approach:
  - Formal description of algorithms
  - Proofs of correctness and complexity
  - No implementation or experiments
  - Empirical analysis of coverage after adding constraints

Empirical Research

- Empirical studies of language and computation
- Studies of models and algorithms applied to data
- Claims justified by experiments and statistical inference
- Explicit relation to real-world problems and data

Empirical Research



Täckström, O., Das, D., Petrov, S., McDonald, R. and Nivre, J. (2013)
Token and Type Constraints for Cross-Lingual Part-of-Speech Tagging.
Transactions of the Association for Computational Linguistics 1, 1–12.

- Contribution:
  - Latent variable CRFs for unsupervised part-of-speech tagging
  - Learning from both type and token constraints
- Approach:
  - Formal description of mathematical model
  - Statistical inference for learning and evaluation
  - Multilingual data sets used in experiments

Applications and Tools

- Design and construction of LT systems
- Primarily end-to-end applications (user-oriented)
- Claims often justified by proven experience
- May include experimental evaluation or user study

Applications and Tools

Gotti, F., Langlais, P. and Lapalme, G. (2014)
Designing a Machine Translation System for Canadian Weather Warnings:
A Case Study. *Natural Language Engineering* 20(3): 399–433.

- Contribution:
  - In-depth description of design and application development
  - Extensive evaluation in the context of application (real users)
- Approach:
  - Case study – concrete instance in context
  - Semi-formal system description (flowcharts, examples)
  - Statistical inference for evaluation

Resources and Evaluation

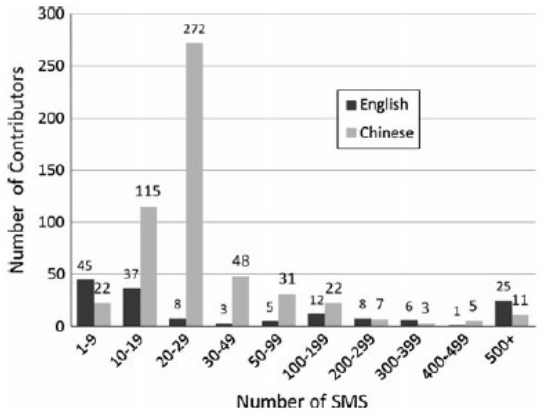
Resources

- Collection and annotation of data (for learning and evaluation)
- Design and construction of knowledge bases (grammars, lexica)

Evaluation

- Protocols for (empirical) evaluation
  - Intrinsic evaluation – task performance
  - Extrinsic evaluation – effect on end-to-end application
- Methodological considerations:
  - Selection of test data (sampling)
  - Evaluation metrics (intrinsic, extrinsic)
  - Significance testing (statistical inference)

Resources and Evaluation



Chen, T. and Kan, M.-Y. (2013)
Creating a Live, Public Short Message Service Corpus:
The NUS SMS Corpus. *Language Resources and Evaluation* 47:299–335.

- Contribution:
  - Free SMS corpus in English and Chinese ($>$ 70,000 msgs)
  - Discussion of methodological considerations
- Approach:
  - Crowdsourcing using mobile phone apps
  - Automatic anonymization using regular expressions
  - Linguistic annotation as future plans

Language Technology as a Science

- Scientific reasoning
  - Deduction common in theoretical research
  - Induction underlies machine learning and statistical evaluation
  - Inference to the best explanation in experimental studies
- Scientific explanation
  - Explanations based on general laws are rare
  - Explanations based on statistical generalizations are the norm
- Reproducibility/replicability
  - Important in theory but problematic in practice
  - Recent initiatives to publish data and software with papers

    Fokkens et al. (2013) Offspring from Reproduction Problems: What Replication Failure Teaches Us. In *Proceedings of ACL*, 1691–1701.

Language Technology as a Science

- The "empirical revolution" in language technology
  - Before 1990: Rationalist approaches and qualitative evaluation
  - Today: Empirical approaches and quantitative evaluation
- What happened?
  - Paradigm shift in Kuhn's sense?
  - Just another swing of the pendulum?
  - Language technology becoming a mature science?

Ethics in Language Technology

- Increasing attention in the (larger) community
- Some issues raised by Hovy and Spruit:
  - Exclusion – data bias
  - Overgeneralization – modeling bias
  - Dual-use problems
- First Workshop on Ethics in NLP held in 2017

Coming up

- Take home exam
  - Handed out: September 13 (afternoon)
  - Deadline: September 20
  - Anonymous, so do not write your name!
  - Studentportalen used for handing out and submitting
- Start thinking about your individual project

Coming up

- Literature seminars:
  - 2–3 articles to read per seminar
  - One person repsonsible for presenting each article
    - short summary
    - main points, strengths, problems, difficulties
    - points of discussion
  - Everyone is expected to have read all articles and to contribute to discussions!
  - Bring the articles to the semianr (on paper or electronically)
  - Rooms on the schedule in the order of groups: UD, mling, aip
  - Seminars on October 2 will be moved; each supervisor will discuss new times on Friday

Reminder deadlines etc.

- All course deadlines are strict!
- Hand in to studentportalen at the latest 23.59. Then it closes.
- Backup deadlines specified on the course web page (not recommended!)

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- Take home exam:
  - Individual examination
  - No cooperation