Language Technology: Research and Development

Language Technology Research and Development

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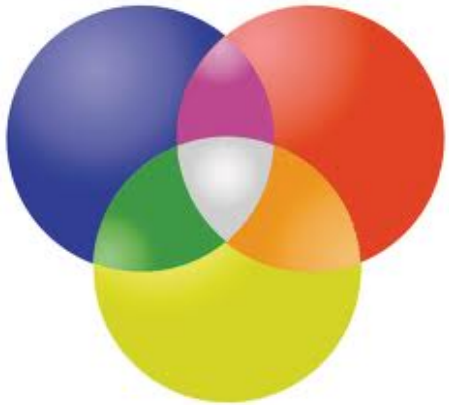
Class Representatives

- Master program meeting November 2, 14-16
  - For students and staff
- Each class should have three representatives
- Elect them somehow, and let Mats know who they are!

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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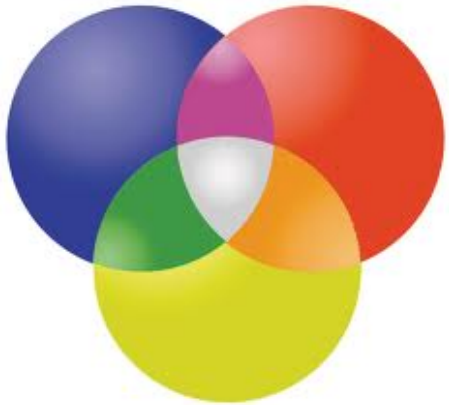

Computational Linguistics (CL)

- 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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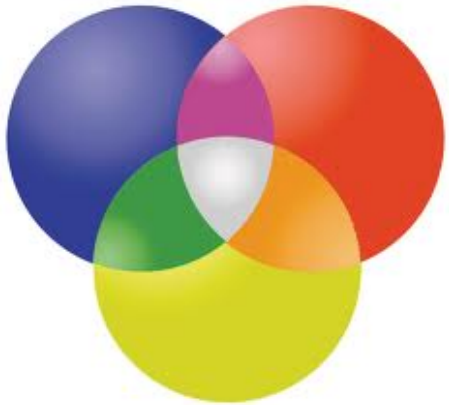

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Natural Language Processing (NLP)

- Study of c ing natural language

Often used synonymously!

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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

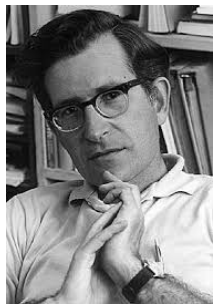
Statistics

- 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)

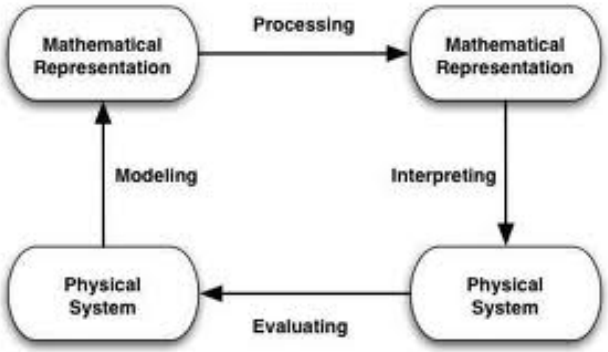
Computer Science

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

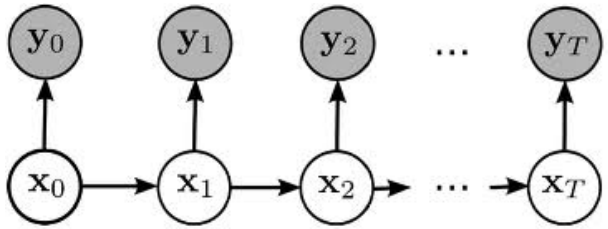
Descriptive statistics

- 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 Transaction of the ACL (TACL):

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

Language Technology R&D

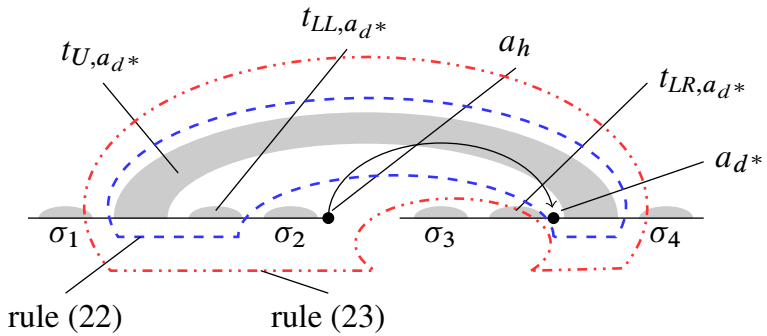
Sections in Transaction of the ACL (TACL):

- 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



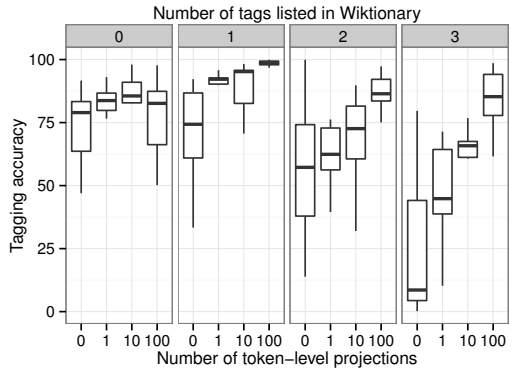
Satta, G. and Kuhlmann, M. (2013)
Efficient Parsing for Head-Split Dependency Trees.
Transactions of the Association for Computational Linguistics 1, 267–278.

- 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

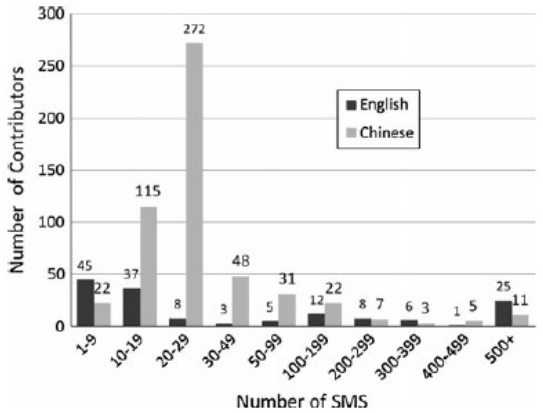
Resources

- 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.

Ethics for NLP

- Receiving increasingly more attention!
- Some issues: (Hovy and Spruit, 2016)
  - Exclusion
  - Overgeneralization
  - Topic exposure problems
  - Dual-use problems
- 1st workshop on Ethics in NLP, 2017 (http://www.ethicsinnlp.org/)

Science or Engineering?

- Is NLP/CL science or engineering?
- Characteristics of science: (Overton opinion)
  1. It is guided by natural law
  2. It has to be explanatory by reference to nature law
  3. It is testable against the empirical world
  4. Its conclusions are tentative, i.e. are not necessarily the final word
  5. It is falsifiable

Coming up

- Take home exam
  - Handed out: September 22
  - Deadline: September 29
  - Studentportalen used for handing out and submitting
- Literature seminars: now (nearly) finalized
  - 2–3 articles to read for next Wednesday/Thursday
  - Check the schedule for updates!
  - Everyone is expected to contribute to discussions!

Reminder deadlines etc.

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- Extra deadline 1 month after original deadline (not recommended!)

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- Take home exam:
  - Individual examination
  - No cooperation