CS6784 - Advanced Topics in Machine Learning

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Outline of Today

- **Introduction**
- **Overview of Class Topics**
  - Structured Prediction
  - Learning with Humans in the Loop
  - Understanding Archives
- **Administrivia**
  - Pre-Requisites
  - Credit Options and Format
  - Project
  - Course Material
  - Office Hours

Topic 1

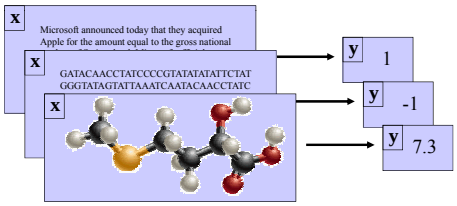
Structured Output Prediction

Conventional Supervised Learning

- **Find function from input space *X* to output space *Y***

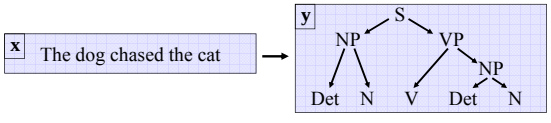
$$h : X \longrightarrow Y$$

such that the prediction error is low.



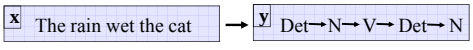
Examples of Complex Output Spaces

- **Natural Language Parsing**
  - Given a sequence of words *x*, predict the parse tree *y*.
  - Dependencies from structural constraints, since *y* has to be a tree.



Examples of Complex Output Spaces

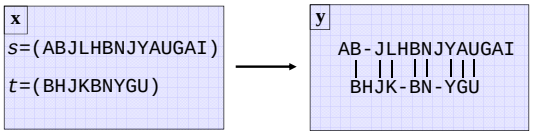
- **Part-of-Speech Tagging**
  - Given a sequence of words *x*, predict sequence of tags *y*.
  - Dependencies from tag-tag transitions in Markov model.



→ Similarly Named-Entity Recognition, Protein Intron Tagging, etc.

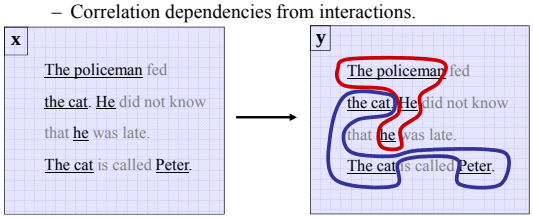
Examples of Complex Output Spaces

- **Protein Sequence Alignment**
  - Given two sequences $x=(s,t)$, predict an alignment y.
  - Structural dependencies, since prediction has to be a valid global/local alignment.



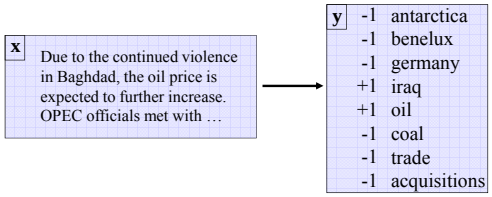
Examples of Complex Output Spaces

- **Noun-Phrase Co-reference**
  - Given a set of noun phrases x, predict a clustering y.
  - Structural dependencies, since prediction has to be an equivalence relation.
  - Correlation dependencies from interactions.



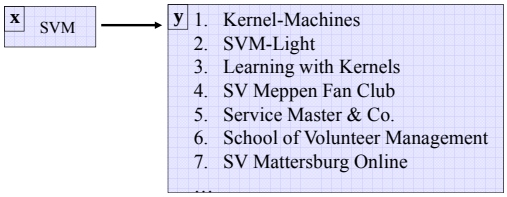
Examples of Complex Output Spaces

- **Multi-Label Classification**
  - Given a (bag-of-words) document x, predict a set of labels y.
  - Dependencies between labels from correlations between labels ("iraq" and "oil" in newswire corpus)



Examples of Complex Output Spaces

- **Information Retrieval**
  - Given a query x, predict a ranking y.
  - Dependencies between results (e.g. avoid redundant hits)
  - Loss function over rankings (e.g. AvgPrec)

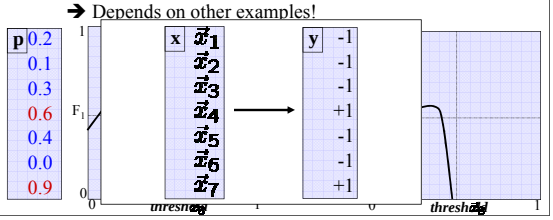


Examples of Complex Output Spaces

- **Non-Standard Performance Measures (e.g. F_1-score, Lift)**
  - F_1-score: harmonic average of precision and recall

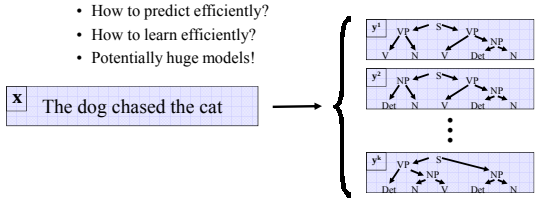
$$F_1 = \frac{2\,Prec\,Rec}{Prec+Rec}$$

  - New example vector $\vec{x}_8$. Predict $y_8=1$, if $P(y_8=1|\vec{x}_8)=0.4$?
    - ➔ Depends on other examples!



Why is Structured Output Prediction Interesting?

- **Application Perspective**
  - Many interesting real-world problems have structure in outputs
- **Research Perspective**
  - Like a multi-class problem with exponentially many classes!
    - How to predict efficiently?
    - How to learn efficiently?
    - Potentially huge models!



Overview: Structured Output Prediction

- **Definition of Problem**
- **Existing methods and their properties / limitations**
  - Generative models
  - Structural SVMs and other maximum margin methods
  - Conditional Random Fields
  - Search-based methods
  - Gaussian Processes
  - Kernel Dependency Estimation
- **Applications**
  - Search engines
  - Natural language processing
  - Reinforcement learning
  - Probabilistic reasoning
  - Computational biology

Topic 2

Learning with Humans in the Loop

Interactive Learning Systems

- **WHILE(forever)**
  - "System" presents options to the user
  - User examines the "Options" and reacts to them
  - "System" observes the selection and learns from it
- **"System" / "Options" =**
  - Search engine / search results
  - Movie recommender system / recommended movies
  - Online shopping site / products to buy
  - GPS navigation software / route
  - Spelling correction in word processor / word
  - Social network extension / friend
  - Twitter / post

Implicit Feedback in Web Search

- **Observable actions**
  - Queries / reformulations
  - Clicks
  - Order, dwell time
  - Etc.
- **Implicit feedback**
  - Personalized
  - Democratic
  - Timely
  - Human intelligence
  - Cheap
  - Abundant

Does User Behavior Reflect Retrieval Quality?

User Study in ArXiv.org

- Natural user and query population.
- User in natural context, not lab.
- Live and operational search engine.
- Ground truth by construction

ORIG ≻ SWAP2 ≻ SWAP4

- ORIG: Hand-tuned fielded
- SWAP2: ORIG with 2 pairs swapped
- SWAP4: ORIG with 4 pairs swapped

ORIG ≻ FLAT ≻ RAND

- ORIG: Hand-tuned fielded
- FLAT: No field weights
- RAND : Top 10 of FLAT shuffled

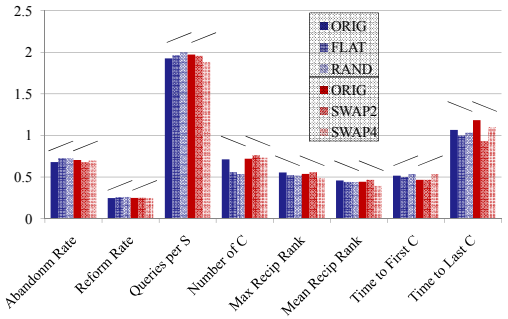
[Radlinski

Absolute Metrics: Metrics

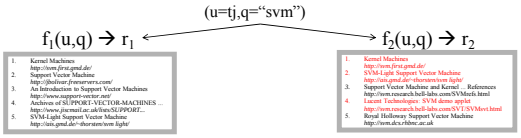
Name	Description	Aggre-gation	Hypothesized Change with Decreased Quality
Abandonment Rate	% of queries with no click	N/A	Increase
Reformulation Rate	% of queries that are followed by reformulation	N/A	Increase
Queries per Session	Session = no interruption of more than 30 minutes	Mean	Increase
Clicks per Query	Number of clicks	Mean	Decrease
Max Reciprocal Rank*	1/rank for highest click	Mean	Decrease
Mean Reciprocal Rank*	Mean of 1/rank for all clicks	Mean	Decrease
Time to First Click*	Seconds before first click	Median	Increase
Time to Last Click*	Seconds before final click	Median	Decrease

(*) only queries with at least one click count

Absolute Metrics: Results

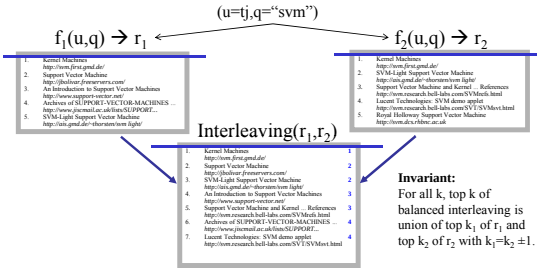


Paired Comparisons: What to Measure?



Interpretation: $(r_1 \succ r_2) \leftrightarrow \text{clicks}(r_1) > \text{clicks}(r_2)$

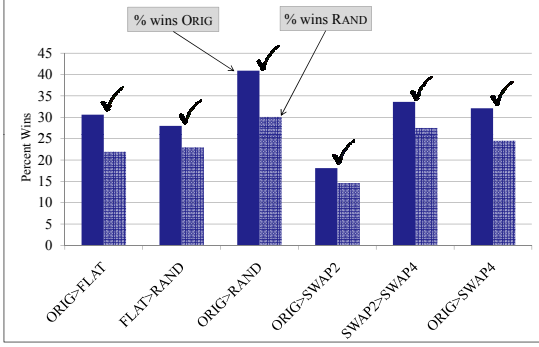
Paired Comparisons: Balanced Interleaving



Invariant:
For all k, top k of balanced interleaving is union of top k_1 of r_1 and top k_2 of r_2 with $k_1=k_2 \pm 1$.

Interpretation: $(r_1 \succ r_2) \leftrightarrow \text{clicks}(\text{topk}(r_1)) > \text{clicks}(\text{topk}(r_2))$

Balanced Interleaving: Results



Issues in Learning with Humans

- **Presentation Bias**
  - Get accurate training data out of biased feedback
  - Use randomization to collect unbiased data
  - Experiment design
- **Online Learning**
  - Exploration/exploitation trade-offs
  - Observational vs. experimental data
  - Ability to run interactive experiments with users
- **Measuring User Satisfaction**
  - Turning behavior into evaluation measure

Overview: Learning with Humans

- **Methods**
  - Online learning and multi-armed bandits
  - Methods for interpreting user behavior
  - Matrix decomposition methods for recommendation
  - Active learning
- **Applications**
  - Information retrieval
  - Recommender systems
  - Online shopping
  - Mechanical turk
  - Web server usage

Topic 3

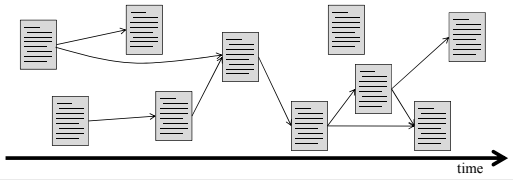
Understanding Archives

Archives

Motivation: We now have more then >10 years of online

- Newspaper archives
- Conference proceeding
- Personal email and photos
- Etc.

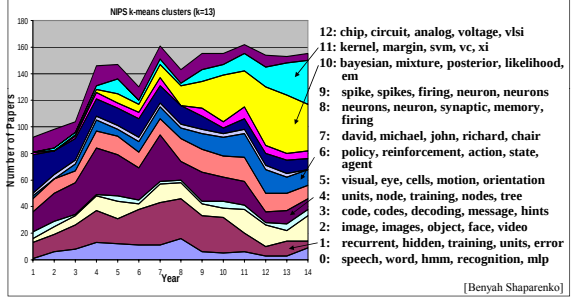
- **Archival, self-referential process of corpus development**



ML Task: Information Genealogy

- **Task: Understand where information originates, how it spreads, and how information streams evolve over time**
  - How did the topics in the NIPS conference evolve and who were the most influential authors driving the change?
  - Did one news article influence another article?
  - Who are the bloggers that are ahead of the curve?
  - An automatic personal diary from email and photos.
  - Etc.

Summarizing Temporal Development: Neural Information Processing Systems (NIPS) 1987 - 2000



[Benyah Shaparenko]

Identifying Dependencies and Influence

Which papers were influenced by "Shrinking the Tube: a New Support Vector Regression Algorithm" written by B. Schoelkopf et al.?

- Assume unigram word distribution is mixture of past papers
- Likelihood ratio test for non-zero mixture weight (convex program)

log(Λ(d))	Cite?	Title and Authors
321.2	No	"Support Vector Method for Novelty Detection", B. Schoelkopf, R. Williamson, A. Smola, J. Shawe-Taylor, J. Platt.
221.8	Yes	"An Improved Decomposition Algorithm for Regression Support Vector Machines", Pavel Laskov.
219.9	Yes	"v-arc: Ensemble Learning in the Presence of Outliers", G. Raetsch, B. Schoelkopf, A. Smola, K. Miller, T. Onoda, S. Mims.
184.6	No	"Fast Training of Support Vector Classifiers", F. Perez-Cruz, P. Alarcon-Diana, A. Navia-Vazquez, A. Artes-Rodriguez.
168.9	Yes	"Uniqueness of the SVM Solution", C. Burges, D. Crisp.

[ShapaJo07]

Identifying Key Documents: NIPS

Score	Year	Cites	Paper Title and Authors
1.167	1996	128	"improving the accuracy and speed of support vector machines" by chris j.c. burges, b. schoelkopf
1.128	1999	17 (466)	"using analytic qp and sparseness to speed training of support vector machines" by john c. platt
0.986	1999	18	"regularizing adaboost" by gunnar raetsch, takashi onoda, klaus-robert mueller
0.953	1996	41 (3711)	"support vector method for function approximation, regression, and signal processing" by v. vapnik, s. golowich, a. smola
0.945	1998	27	"training methods for adaptive boosting of neural networks" by holger schwenk, yoshua bengio
0.945	1997	3	"modeling complex cells in an awake macaque during natural image viewing" by william e. vinje, jack l. gallant
0.934	1998	17	"em optimization of latent-variable density models" by chris bishop, markus svensen, chris william
0.934	1995	584	"a new learning algorithm for blind signal separation" by s. amari, a. cichocki, h. h. yang

[ShapaJo07]

Overview: Understanding Archives

- **Idea flow**
  - Dependencies between documents and authors
- **Temporal development of content**
  - Bursts and topic drift
- **Meta data and access data**
  - Using temporally grown link structure
  - Using access logs to identify relationships
- **Personal information management**
  - Desktop search
  - Photo archives

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- **Administrivia**
  - Pre-Requisites
  - Credit Options and Format
  - Project
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Pre-Requisites

- **This is not an introductory Machine Learning class!**
- **You need to satisfy one of the following ML pre-reqs:**
  - Successfully taken CS4780 "Machine Learning"
  - Successfully taken CS6780 "Advanced Machine Learning"
  - Successfully taken a comparable "Intro to ML" class (*)
  - Acquired the equivalent ML knowledge in some other way (e.g. strong background in Statistics + ML textbook) (*)
- **Basic probability and linear algebra**
- **Programming skills required for many projects**

(*) means talk to me

Format of Class

- **Lectures**
- **Research papers**
  - Everybody reads the paper in preparation for class
  - Some assignment (e.g. quiz, review, critique) about each paper
  - One student presents the paper in class
    - Slide presentation
    - Create examples, demo software, experiments etc. that help understand the paper
    - Prepare discussion topics

    → I'll give you feedback before your presentation
- **Project**

Project

- **Full Semester Project**
  - Topic of your choice that relates to CS6784
  - Undergrad/MEng students: groups of 3-4
  - Ph.D. students: group or individual
- **Timeline**
  - 2/11: Proposal (10 %)
  - 3/18: First status report (10 %)
  - 4/20: Second status report (10 %)
  - 5/4-6: Project presentation (20 %)
  - 5/16: Final project report (50 %)

Credit Options and Grades

- **Letter grade:**
  - project (50%)
  - paper presentation (25%)
  - assignments (15%)
  - discussion (10%)
- **Pass/Fail:**
  - paper presentation (50%)
  - assignments (30%)
  - discussion (20%)
- **Audit:**
  - not allowed, unless you have very good arguments

Course Material

- **Background Reading**
  - T. Mitchell, "Machine Learning", McGraw Hill, 1997.
  - B. Schoelkopf, A. Smola, "Learning with Kernels", MIT Press, 2001. (online)
  - C. Bishop, "Pattern Recognition and Machine Learning", Springer, 2006.
  - R. Duda, P. Hart, D. Stork, "Pattern Classification", Wiley, 2001.
  - T. Hastie, R. Tishirani, and J. Friedman, "The Elements of Statistical Learning", Springer, 2001.
  - N. Cristianini, J. Shawe-Taylor, "Introduction to Support Vector Machines", Cambridge University Press, 2000. (online)
  - Ethem Alpaydin, "Introduction to Machine Learning", MIT Press, 2004.
- **Slides, Notes and Papers**
  - Slides available on course homepage
  - Papers on course homepage

How to Get in Touch

- **Course Web Page**
  - http://www.cs.cornell.edu/Courses/cs6784/2010sp/
- **Email**
  - Thorsten Joachims: tj@cs.cornell.edu
- **Office Hours**
  - Tuesdays 4:00pm – 5:00pm, 4153 Upson Hall