Quality Control - part 4

Crowdsourcing and Human Computation

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Website: crowdsourcing-class.org

Different Mechanisms for Quality Control

- Aggregation and redundancy

- Embedded gold standard data

- Economic incentives

- Reputation systems

- **Statistical models**

Expectation Maximization algorithm

- EM is an algorithm for finding the probabilities of unobserved variables

- We will use it to estimate how accurate workers' labels are, and infer how good each worker is

- This is more sophisticated than voting

Dawid and Skene (1977)

- *Maximum Likelihood Estimation of Observer Error-rates using the EM Algorithm*

- Examined application to medical diagnosis

- Patients are sometimes treated by multiple physicians, who can give different diagnoses

- Why? Doctors may has different questions. Patient may describe history differently. Doctors may classify symptoms differently

Observer Error

- Given that different doctors have different opinions, they can't all be right.

- How often do individual physicians suffer from "observer error"? Are their errors systematic?
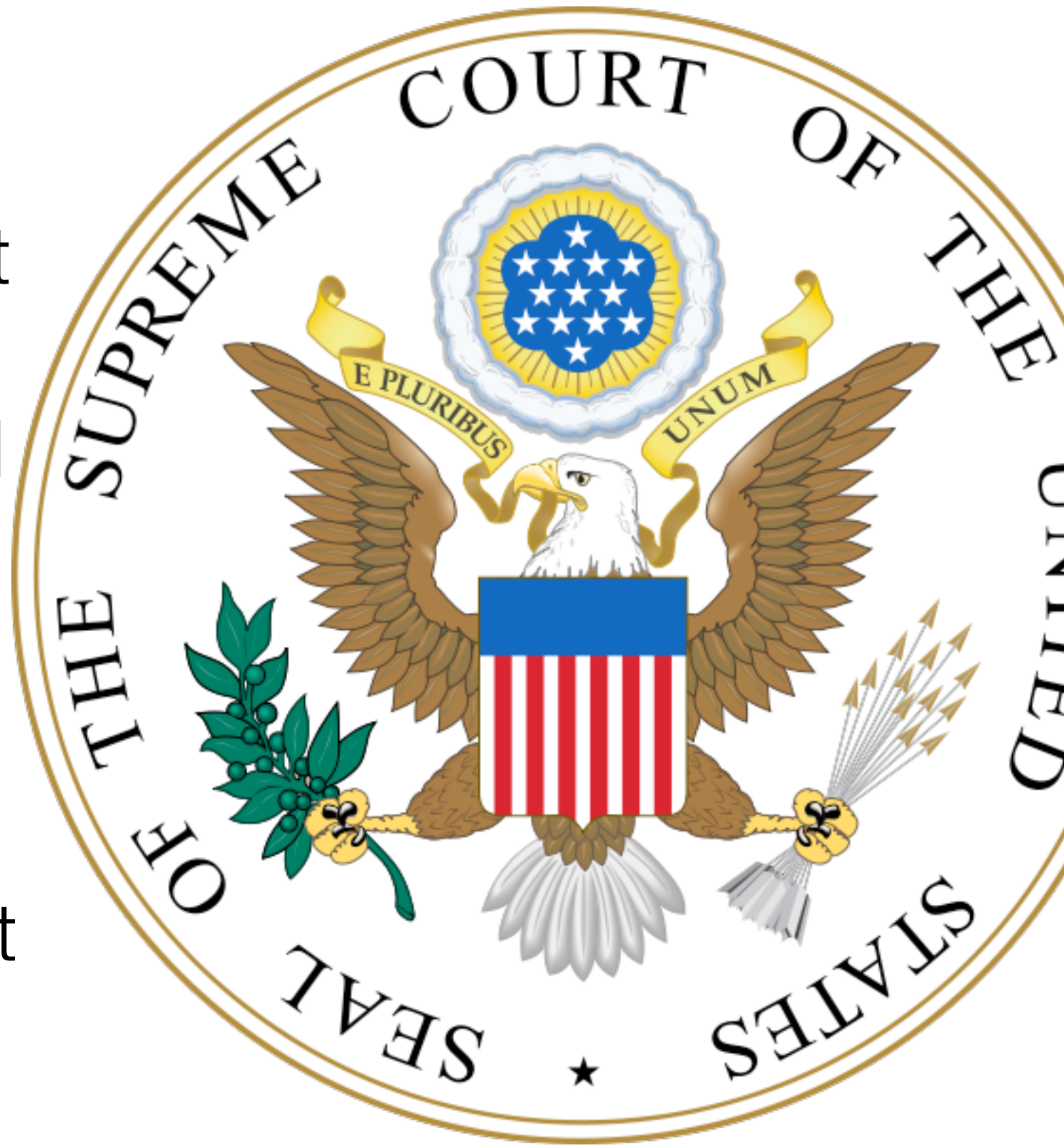
- Answers depend on the "true" diagnosis

Observer Error

- Observer error would be easy to calculate if we had ground truth

- Simply count the misdiagnoses and divide by the total number of diagnoses

- However, sometimes it is impossible to know what diagnosis is correct. Same set of symptoms can arise from multiple root causes.

"I know it when I see it"

I shall not today attempt further to define "hard-core pornography"; and perhaps I could never succeed in intelligibly doing so. But I know it when I see it.
—Justice Potter Stewart

url	worker1	worker2	worker3	worker4	worker5
sunnyfun.com	porn	not	not	not	porn
sex-mission.com	porn	porn	porn	porn	porn
google.com	not	porn	not	not	porn
youporn.com	porn	porn	porn	porn	not
yahoo.com	porn	not	not	not	porn

Solution?

- Can't have Justice Stewart rule on everything

- Instead, we will apply Dawid and Skene's EM algorithm, which iteratively

  1. Estimates the correct answers, using labels from multiple workers, and accounts for the quality of each worker

  2. Estimates the quality of the workers by comparing the submitted answers to the inferred correct answers

Inputs

- a set of **N** objects o$_1$ ... o$_N$
  google.com, panda-cam.gov, sex-mission.com, sunnyfun.com, youporn.com

- a set of **L** possible labels:
  {porn, not porn}

- Labels for each object by **K** workers
  worker1, worker2, worker3, worker4, worker5

Goal 1

- Recover the true class label **T**(o_n) for each object o_n when "gold" truth is unknown

- Since the true labels are not known / never directly observed, they are called ***latent*** variables

Goal 2

- For each worker who contributed labels, calculate their accuracy or reliability

- To calculate accuracy show how often they mistakenly choose one label when a different one is the actual truth

Chicken and egg problem

- If we knew what the **true class labels** were for each object for each object, then we could compute each Turker's accuracy

- If we had **accuracies for every Turker**, then we could infer what the true label for each object should be

Input: Labels $l[k][n]$ from worker (k) to object o_n,

Output: Confusion matrix $\pi_{ij}^{(k)}$ for each worker (k), Correct labels $T(o_n)$ for each object o_n, Class priors $Pr\{C\}$ for each class C

1 Initialize error rates $\pi_{ij}^{(k)}$ for each worker (k) (e.g., assume each worker is perfect);

2 Initialize correct label for each object $T(o_n)$ (e.g., using majority vote);

3 while *not converged* **do**

4   Estimate the correct label $T(o_n)$ for each object, using the labels $l[\cdot][n]$ assigned to o_n by workers, weighting the votes using the error rates $\pi_{ij}^{(k)}$;

5   Estimate the error rates $\pi_{ij}^{(k)}$, for each worker (k), using the correct labels $T(o_n)$ and the assigned labels $l[k][n]$;

6   Estimate the class priors $Pr\{C\}$, for each class C;

7 end

8 return *Estimated error rates* $\pi_{ij}^{(k)}$, *Estimated correct labels* $T(o_n)$, *Estimated class priors* $Pr\{C\}$

Algorithm 1: The EM algorithm for worker quality estimation.

Input

url	worker1	worker2	worker3	worker4	worker5
sunnyfun.com	porn	not	not	not	porn
sex-mission.com	porn	porn	porn	porn	porn
google.com	not	porn	not	not	porn
youporn.com	porn	porn	porn	porn	not
yahoo.com	porn	not	not	not	porn

Output: "True" Labels

url	True Labels
sunnyfun.com	not
sex-mission.com	porn
google.com	not
youporn.com	porn
yahoo.com	not

Output: Worker Accuracies

Guess

w1	porn	not
porn	100%	0%
not	67%	33%

Truth

w2	porn	not
porn	100%	0%
not	33%	67%

w3	porn	not
porn	100%	0%
not	0%	100%

Guess

w4	porn	not
porn	100%	0%
not	0%	100%

Truth

w5	porn	not
porn	50%	50%
not	100%	0%

Initialize

Guess

w1	porn	not
porn	100%	0%
not	0%	100%

Truth

w2	porn	not
porn	100%	0%
not	0%	100%

w3	porn	not
porn	100%	0%
not	0%	100%

Guess

w4	porn	not
porn	100%	0%
not	0%	100%

Truth

w5	porn	not
porn	100%	0%
not	0%	100%

Initialize with majority vote

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		40%	60%
sex-mission.com	porn	porn	porn	porn	porn		100%	0%
google.com	not	porn	not	not	porn		40%	60%
youporn.com	porn	porn	porn	porn	not		80%	20%
yahoo.com	porn	not	not	not	porn		40%	60%

Pretend your labels are correct

url	worker 1	worker 2	worker 3	worker 4	worker 5
sunnyfun.com	porn	not	not	not	porn
sex-mission.com	porn	porn	porn	porn	porn
google.com	not	porn	not	not	porn
youporn.com	porn	porn	porn	porn	not
yahoo.com	porn	not	not	not	porn

porn	not porn
0%	100%
100%	0%
0%	100%
100%	0%
0%	100%

Re-Calculate Worker Scores

w1	Guess	
	porn	not
Truth porn	0	0
not	1	0

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		0	1
sex-mission.com	porn	porn	porn	porn	porn		1	0
google.com	not	porn	not	not	porn		0	1
youporn.com	porn	porn	porn	porn	not		1	0
yahoo.com	porn	not	not	not	porn		0	1

Re-Calculate Worker Scores

Guess

w1	porn	not
porn	1	0
not	1	0

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		0	1
sex-mission.com	porn	porn	porn	porn	porn		1	0
google.com	not	porn	not	not	porn		0	1
youporn.com	porn	porn	porn	porn	not		1	0
yahoo.com	porn	not	not	not	porn		0	1

Re-Calculate Worker Scores

Guess

w1	porn	not
porn	1	0
not	1	1

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

Guess

w1	porn	not
porn	2	0
not	1	1

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

Guess

w1	porn	not
porn	2	0
not	2	1

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

Guess

w1	porn	not
porn (Truth)	100%	0%
not (Truth)	67%	33%

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

Guess		
w2	porn	not
porn	0	0
not	0	1

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		0	1
sex-mission.com	porn	porn	porn	porn	porn		1	0
google.com	not	porn	not	not	porn		0	1
youporn.com	porn	porn	porn	porn	not		1	0
yahoo.com	porn	not	not	not	porn		0	1

Re-Calculate Worker Scores

Guess		
w2	porn	not
porn	1	0
not	0	1

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		0	1
sex-mission.com	porn	porn	porn	porn	porn		1	0
google.com	not	porn	not	not	porn		0	1
youporn.com	porn	porn	porn	porn	not		1	0
yahoo.com	porn	not	not	not	porn		0	1

Re-Calculate Worker Scores

Guess

w2	porn	not
porn	1	0
not	1	1

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

Guess

w2	porn	not
Truth porn	2	0
not	1	1

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

w2	Guess porn	not
Truth porn	2	0
not	1	2

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

Guess

w2	porn	not
Truth porn	100%	0%
not	33%	67%

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

w3	Guess porn	not
Truth porn	0	0
not	0	1

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		0	1
sex-mission.com	porn	porn	porn	porn	porn		1	0
google.com	not	porn	not	not	porn		0	1
youporn.com	porn	porn	porn	porn	not		1	0
yahoo.com	porn	not	not	not	porn		0	1

Re-Calculate Worker Scores

w3	porn	not
porn	1	0
not	0	1

Guess

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		0	1
sex-mission.com	porn	porn	porn	porn	porn		1	0
google.com	not	porn	not	not	porn		0	1
youporn.com	porn	porn	porn	porn	not		1	0
yahoo.com	porn	not	not	not	porn		0	1

Re-Calculate Worker Scores

Guess

w3	porn	not
porn	1	0
not	0	2

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

Guess

w3	porn	not
porn	2	0
not	0	2

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

w3	Guess porn	Guess not
Truth porn	2	0
Truth not	0	3

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

Guess

w3	porn	not
porn	100%	0%
not	0%	100%

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		0	1
sex-mission.com	porn	porn	porn	porn	porn		1	0
google.com	not	porn	not	not	porn		0	1
youporn.com	porn	porn	porn	porn	not		1	0
yahoo.com	porn	not	not	not	porn		0	1

Re-Calculate Worker Scores

w4	porn	not
porn	0	0
not	0	1

Guess / Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		0	1
sex-mission.com	porn	porn	porn	porn	porn		1	0
google.com	not	porn	not	not	porn		0	1
youporn.com	porn	porn	porn	porn	not		1	0
yahoo.com	porn	not	not	not	porn		0	1

Re-Calculate Worker Scores

Guess		
w4	porn	not
porn	1	0
not	0	1

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

	Guess	
w4	porn	not
porn	1	0
not	0	2

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

	Guess	
w4	porn	not
porn	2	0
not	0	2

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

Guess

w4	porn	not
porn	2	0
not	0	3

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

Guess

w4	porn	not
porn	100%	0%
not	0%	100%

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

Guess

w5	porn	not
porn (Truth)	0	0
not	1	0

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		0	1
sex-mission.com	porn	porn	porn	porn	porn		1	0
google.com	not	porn	not	not	porn		0	1
youporn.com	porn	porn	porn	porn	not		1	0
yahoo.com	porn	not	not	not	porn		0	1

Re-Calculate Worker Scores

	Guess	
w5	porn	not
Truth porn	1	0
not	1	0

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		0	1
sex-mission.com	porn	porn	porn	porn	porn		1	0
google.com	not	porn	not	not	porn		0	1
youporn.com	porn	porn	porn	porn	not		1	0
yahoo.com	porn	not	not	not	porn		0	1

Re-Calculate Worker Scores

Truth \ Guess (w5)	porn	not
porn	1	0
not	2	0

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

Guess

w5	porn	not
Truth porn	1	1
not	2	0

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		0	1
sex-mission.com	porn	porn	porn	porn	porn		1	0
google.com	not	porn	not	not	porn		0	1
youporn.com	porn	porn	porn	porn	not		1	0
yahoo.com	porn	not	not	not	porn		0	1

Re-Calculate Worker Scores

Guess

w5	porn	not
porn	1	1
not	3	0

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		0	1
sex-mission.com	porn	porn	porn	porn	porn		1	0
google.com	not	porn	not	not	porn		0	1
youporn.com	porn	porn	porn	porn	not		1	0
yahoo.com	porn	not	not	not	porn		0	1

Re-Calculate Worker Scores

Guess

w5	porn	not
porn	1	1
not	3	0

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	0	1
sex-mission.com	porn	porn	porn	porn	porn	1	0
google.com	not	porn	not	not	porn	0	1
youporn.com	porn	porn	porn	porn	not	1	0
yahoo.com	porn	not	not	not	porn	0	1

Re-Calculate Worker Scores

w5	porn	not
porn	50%	50%
not	100%	0%

Guess / Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		0	1
sex-mission.com	porn	porn	porn	porn	porn		1	0
google.com	not	porn	not	not	porn		0	1
youporn.com	porn	porn	porn	porn	not		1	0
yahoo.com	porn	not	not	not	porn		0	1

Update Estimates for True Labels

Guess

w1	porn	not
porn	1.00	0.00
not	0.67	0.33

(Truth — rows: porn, not)

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		1.00	0.67
sex-mission.com	porn	porn	porn	porn	porn			
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

Guess

w2	porn	not
Truth porn	1.00	0.00
not	0.33	0.67

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		1.00	1.34
sex-mission.com	porn	porn	porn	porn	porn			
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

w3	porn	not
porn	1	0
not	0	1

Guess

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		1.00	2.34
sex-mission.com	porn	porn	porn	porn	porn			
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

Guess

w4	porn	not
porn	1	0
not	0	1

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		1.00	3.34
sex-mission.com	porn	porn	porn	porn	porn			
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

Guess

w5	porn	not
porn	0.5	0.5
not	1	0

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		1.50	4.34
sex-mission.com	porn	porn	porn	porn	porn			
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update
Estimates for
True Labels

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		1.50	4.34
sex-mission.com	porn	porn	porn	porn	porn			
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn			
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

w1	porn	not
porn	1.00	0.00
not	0.67	0.33

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		1.00	0.67
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

w2	porn	not
Guess		

Truth		
porn	1.00	0.00
not	0.33	0.67

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		2.00	1.00
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

Guess

w3	porn	not
porn	1	0
not	0	1

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		3.00	1.00
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

Guess

w4	porn	not
porn	1	0
not	0	1

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		4.00	1.00
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

w5	porn	not
porn	0.5	0.5
not	1	0

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		4.50	2.00
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update
Estimates for
True Labels

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		4.50	2.00
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		69%	31%
google.com	not	porn	not	not	porn			
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

Guess

w1	porn	not
porn (Truth)	1.00	0.00
not (Truth)	0.67	0.33

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	0.00	0.33
youporn.com	porn	porn	porn	porn	not		
yahoo.com	porn	not	not	not	porn		

Update Estimates for True Labels

Guess

w2	porn	not
Truth porn	1.00	0.00
not	0.33	0.67

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	1.00	0.67
youporn.com	porn	porn	porn	porn	not		
yahoo.com	porn	not	not	not	porn		

Update Estimates for True Labels

Guess

w3	porn	not
porn	1	0
not	0	1

Truth (vertical label on left of table)

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	1.00	1.67
youporn.com	porn	porn	porn	porn	not		
yahoo.com	porn	not	not	not	porn		

Update Estimates for True Labels

Guess

w4	porn	not
porn	1	0
not	0	1

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	1.00	2.67
youporn.com	porn	porn	porn	porn	not		
yahoo.com	porn	not	not	not	porn		

Update Estimates for True Labels

Guess

w5	porn	not
porn (Truth)	0.5	0.5
not	1	0

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		69%	31%
google.com	not	porn	not	not	porn		1.50	3.76
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		69%	31%
google.com	not	porn	not	not	porn		1.50	3.76
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		69%	31%
google.com	not	porn	not	not	porn		29%	71%
youporn.com	porn	porn	porn	porn	not			
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

w1	porn	not
porn	1.00	0.00
not	0.67	0.33

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	29%	71%
youporn.com	porn	porn	porn	porn	not	1.00	0.67
yahoo.com	porn	not	not	not	porn		

Update Estimates for True Labels

Guess

w2	porn	not
porn (Truth)	1.00	0.00
not (Truth)	0.33	0.67

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	29%	71%
youporn.com	porn	porn	porn	porn	not	2.00	1.00
yahoo.com	porn	not	not	not	porn		

Update Estimates for True Labels

Guess

w3	porn	not
porn	1	0
not	0	1

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	29%	71%
youporn.com	porn	porn	porn	porn	not	3.00	1.00
yahoo.com	porn	not	not	not	porn		

Update Estimates for True Labels

Guess

w4	porn	not
Truth porn	1	0
not	0	1

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	29%	71%
youporn.com	porn	porn	porn	porn	not	4.00	1.00
yahoo.com	porn	not	not	not	porn		

Update Estimates for True Labels

Guess

w5	porn	not
porn (Truth)	0.5	0.5
not	1	0

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	29%	71%
youporn.com	porn	porn	porn	porn	not	4.50	1.00
yahoo.com	porn	not	not	not	porn		

Update Estimates for True Labels

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		69%	31%
google.com	not	porn	not	not	porn		29%	71%
youporn.com	porn	porn	porn	porn	not		4.50	1.00
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		69%	31%
google.com	not	porn	not	not	porn		29%	71%
youporn.com	porn	porn	porn	porn	not		82%	18%
yahoo.com	porn	not	not	not	porn			

Update Estimates for True Labels

Guess

w1	porn	not
porn	1.00	0.00
not	0.67	0.33

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	29%	71%
youporn.com	porn	porn	porn	porn	not	82%	18%
yahoo.com	porn	not	not	not	porn	1.00	0.67

Update Estimates for True Labels

Guess

w2	porn	not
Truth: porn	1.00	0.00
Truth: not	0.33	0.67

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	29%	71%
youporn.com	porn	porn	porn	porn	not	82%	18%
yahoo.com	porn	not	not	not	porn	1.00	1.34

Update Estimates for True Labels

w3	porn	not
porn	1	0
not	0	1

Truth

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	29%	71%
youporn.com	porn	porn	porn	porn	not	82%	18%
yahoo.com	porn	not	not	not	porn	1.00	2.34

Update Estimates for True Labels

Guess

w4	porn	not
Truth porn	1	0
not	0	1

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	29%	71%
youporn.com	porn	porn	porn	porn	not	82%	18%
yahoo.com	porn	not	not	not	porn	1.00	3.34

Update Estimates for True Labels

w5	porn	not
porn	0.5	0.5
not	1	0

Guess (column header), **Truth** (row header)

url	worker 1	worker 2	worker 3	worker 4	worker 5	porn	not porn
sunnyfun.com	porn	not	not	not	porn	26%	74%
sex-mission.com	porn	porn	porn	porn	porn	69%	31%
google.com	not	porn	not	not	porn	29%	71%
youporn.com	porn	porn	porn	porn	not	82%	18%
yahoo.com	porn	not	not	not	porn	1.50	4.34

Update
Estimates for
True Labels

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		69%	31%
google.com	not	porn	not	not	porn		29%	71%
youporn.com	porn	porn	porn	porn	not		82%	18%
yahoo.com	porn	not	not	not	porn		1.50	4.34

Update Estimates for True Labels

url	worker 1	worker 2	worker 3	worker 4	worker 5		porn	not porn
sunnyfun.com	porn	not	not	not	porn		26%	74%
sex-mission.com	porn	porn	porn	porn	porn		69%	31%
google.com	not	porn	not	not	porn		29%	71%
youporn.com	porn	porn	porn	porn	not		82%	18%
yahoo.com	porn	not	not	not	porn		26%	74%

Iteration 0

url	porn	not porn
sunnyfun.com	40%	60%
sex-mission.com	100%	0%
google.com	40%	60%
youporn.com	80%	20%
yahoo.com	40%	60%

Guess

Truth

w1	porn	not
porn	100%	0%
not	0%	100%

w2	porn	not
porn	100%	0%
not	0%	100%

w3&4	porn	not
porn	100%	0%
not	0%	100%

w5	porn	not
porn	100%	0%
not	0%	100%

Iteration 1

url	porn	not porn
sunnyfun.com	26%	74%
sex-mission.com	69%	31%
google.com	29%	71%
youporn.com	82%	18%
yahoo.com	26%	74%

Guess

Truth

w1	porn	not
porn	100%	0%
not	67%	33%

w2	porn	not
porn	100%	0%
not	33%	67%

w3&4	porn	not
porn	100%	0%
not	0%	100%

w5	porn	not
porn	50%	50%
not	100%	0%

Question

- How would you use gold standard data in the EM process?

EM Algorithm

- Re-Calculate Worker Scores over two steps:

  1. Estimate the probability that each answer is correct, using labels from multiple workers weighted by the probability that they are correct

  2. Estimate the quality of the workers by comparing their submitted answers to the inferred correct answers

Confusion Matrix gives us worker error

- From the confusion matrix we can measure the overall error rate for each worker

- Sum of the non-diagonal elements of the confusion matrix (weighted by the priors)

- This results in a single, scalar value as the quality score for each worker

Worker Error

w1	porn	not
porn	100%	0%
not	100%	0%

100

w2	porn	not
porn	100%	0%
not	33%	67%

33

w3&4	porn	not
porn	100%	0%
not	0%	100%

0

w5	porn	not
porn	0%	100%
not	100%	0%

200

Is worker5 the worst?

url	worker1	worker2	worker3	worker4	worker5
google.com	porn	not porn	not porn	not porn	porn
panda-cam.gov	porn	porn	not porn	not porn	porn
sex-mission.com	porn	porn	porn	porn	not porn
sunnyfun.com	porn	not porn	not porn	not porn	porn
youporn.com	porn	porn	porn	porn	not porn

Advanced Topics

- Bias versus error

- How noisy can the workers be and still allow us to still converge to a correct solution?

Bias versus Error

- Error rate alone is not sufficient to measure the inherent value of a worker.

- For example, workers may be careful but biased

- In a non-binary case, this is more apparent

- What if instead of asking our workers to label sites porn or not porn, we asked them to label the G, PG, R, X?

Bias versus Error

- Parents with young children tend to be more conservative

- They tend to classify PG-rated sites as R-rated sites, and R-rated sites as X-rated.

- Such workers give consistently and predictably incorrect answers

- It is possible to automatically correct for bias

Implications

- Unlike with spammers, with biased workers it is possible to "reverse" the errors

- We can recover a label assignment of much higher quality

- In the presence of systematic bias, the naive measurement of error rate results in underestimates of the true quality of the worker

- This potentially leads to incorrect rejections and blocks of legitimate workers

For more details

- Check out two papers by Panos Ipeirotis and his collaborators

- *Managing Crowdsourcing Workers* discusses separating error and bias

- *Get Another Label? Improving Data Quality and Data Mining Using Multiple, Noisy Labelers* discusses how noisy judgements can be, with us still getting good quality results

Questions?