

Assignment Project Exam Help

Introduction to Weak Supervision

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Chris Ré

CS229

Messages for Today

Introduce **two key concepts**:

- **Method of moments** for latent probabilistic variable models
 - *They have provable global solution* (Compare with EM methods)
 - Widely used in “tensor methods”
- **Probability distributions on graphs** (graphical models)
 - Fun facts about Gaussians that are good for your soul (Inverse covariance matrix structure and graphs)
- High-level overview of new area called **weak supervision**.
 - Why supervision is so critical in this age and resources (nascent)
 - Very recent work & biased by our own group’s work—but you have likely used it today!

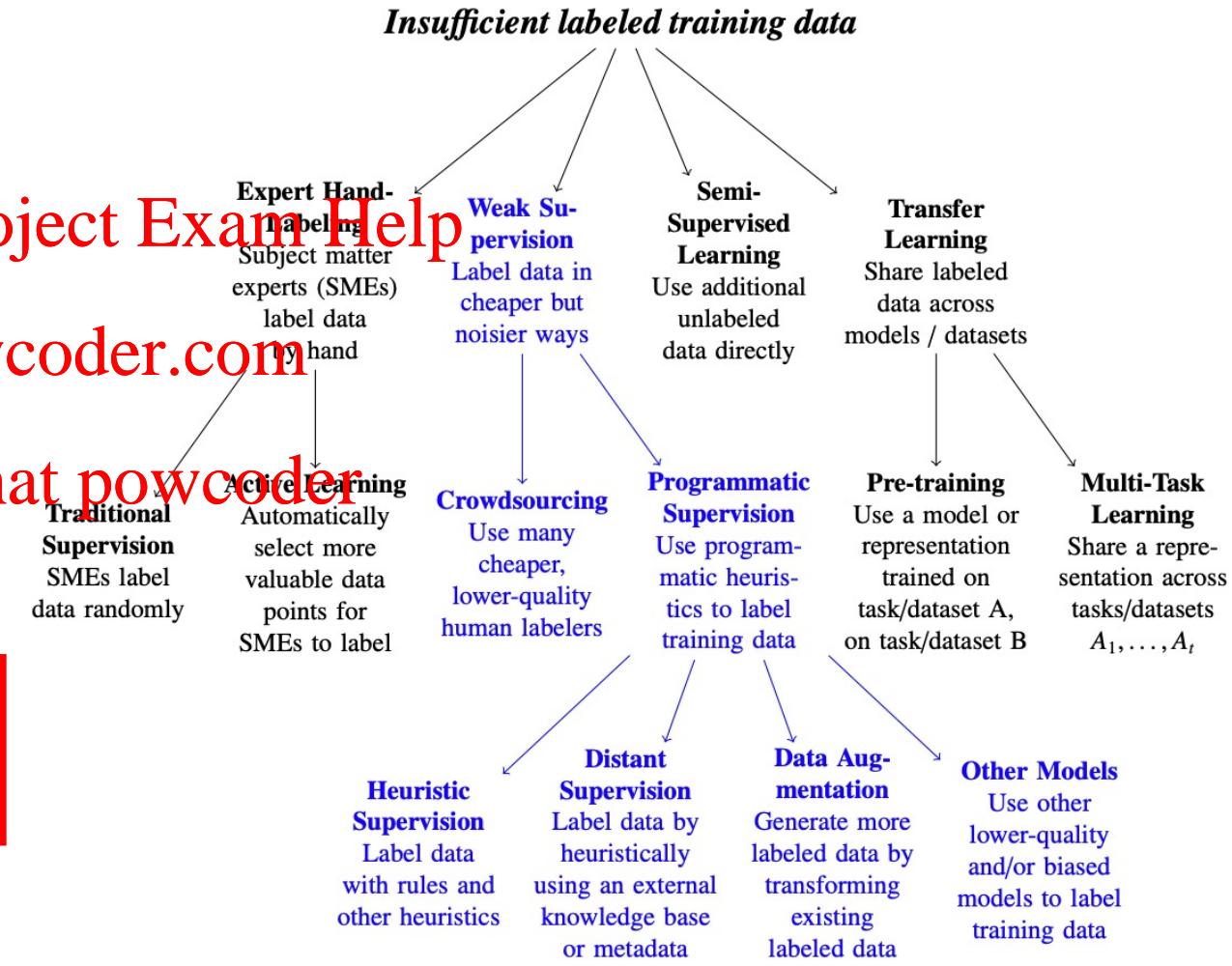
Various techniques for limited labeled data

- **Active learning:** Select points to label more intelligently
- **Semi-supervised learning:** Use unlabeled data as well <https://powcoder.com>
- **Transfer learning:** Transfer from one training dataset to a new task
- **Weak supervision:** Label data in cheaper, higher-level ways

This lecture.

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Related Work in Weak Supervision

- **Crowdsourcing:** Dawid & Skene 1979, Karger et. al. 2011, Dalvi et. al. 2013, Ruvolo et. al. 2013, Zhang et. al. 2014, Berend & Kontorovich 2014, etc.
- **Distant Supervision:** Mintz et. al. 2009, Alfonescá et. al. 2012, Takamatsu et. al. 2012, Roth & Klakow 2013, Augenstein et. al. 2015, etc.
- **Co-Training:** Blum & Mitchell 1998
- **Noisy Learning:** Bootkrajang et. al. 2012, Mnih & Hinton 2012, Xiao et. al. 2015, etc.
- **Indirect Supervision:** Clarke et. al. 2010, Guu et. Al. et. al. 2017, etc.
- **Feature and Class-distribution Supervision:** Zaidan & Eisner 2008, Druck et. al. 2009, Liang et. al. 2009, Mann & McCallum 2010, etc.
- **Boosting & Ensembling:** Schapire & Freund, Platanios et. al. 2016, etc.
- **Constraint-Based Supervision:** Bilenko et. al. 2004, Koestinger et. al. 2012, Stewart & Ermon 2017, etc.

More Related work

- So much more! *Work was inspired by classics and new Cotraining , GANs, capsule networks, semi-supervised learning, crowd-sourcing and so much more!*

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- Please see blog for summary.

<https://www.snorkel.org/blog/weak-supervision>



snorkel

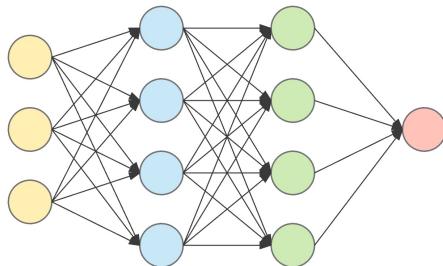
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... Biased by on-going work...
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ML Application =

Model



+

Data

+

Hardware

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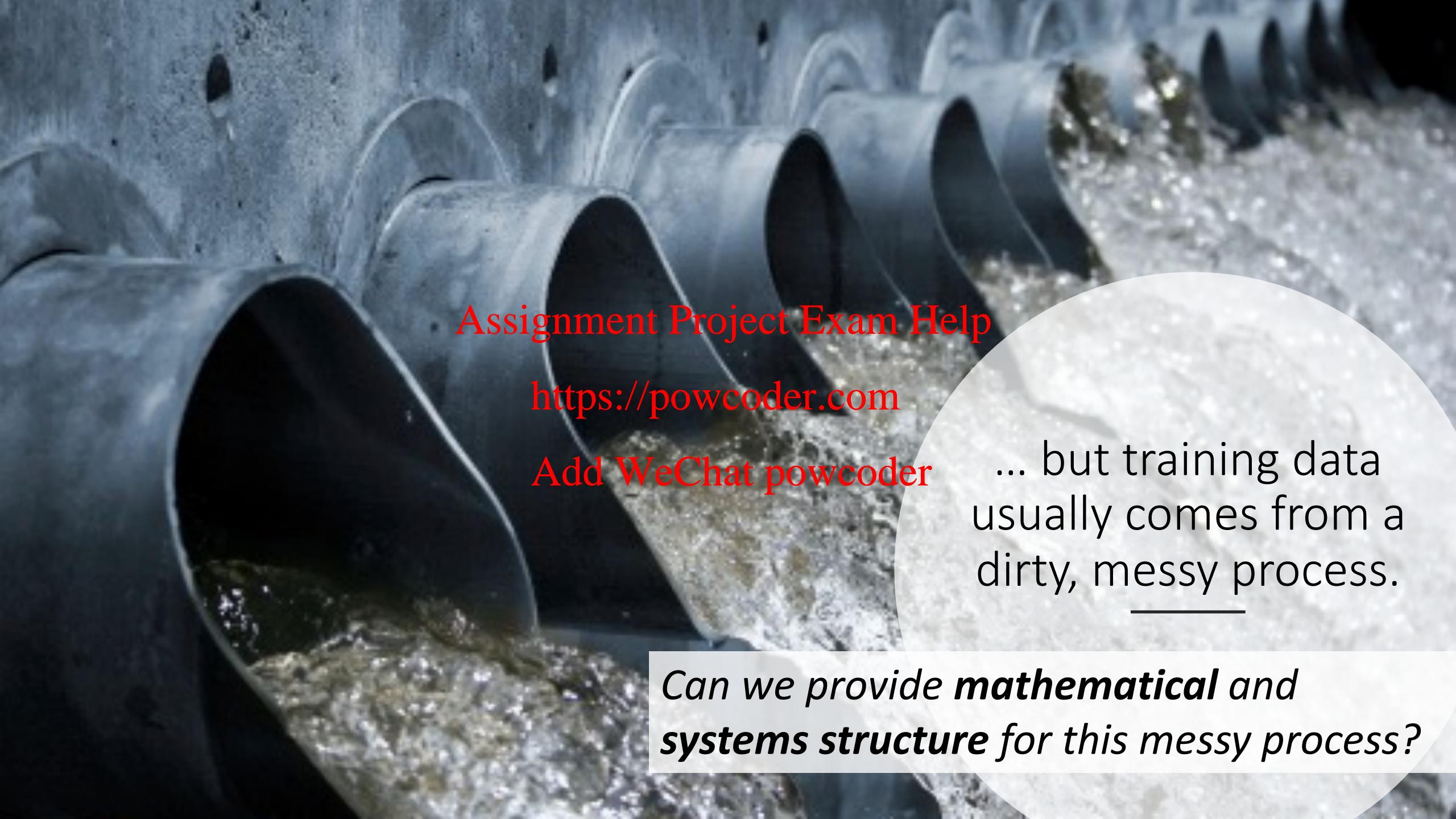


**State-of-the-art models and hardware are available.
Training data is not**



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<https://powcoder.com>
But supervision
comes from god
herself....

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The background image shows a series of large, dark-colored pipes, possibly made of concrete or steel, arranged in a row on a bed of light-colored gravel. The pipes are weathered and have a textured surface. The perspective is from a low angle, looking along the length of the pipes.

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... but training data
usually comes from a
dirty, messy process.

*Can we provide **mathematical** and
systems structure for this messy process?*



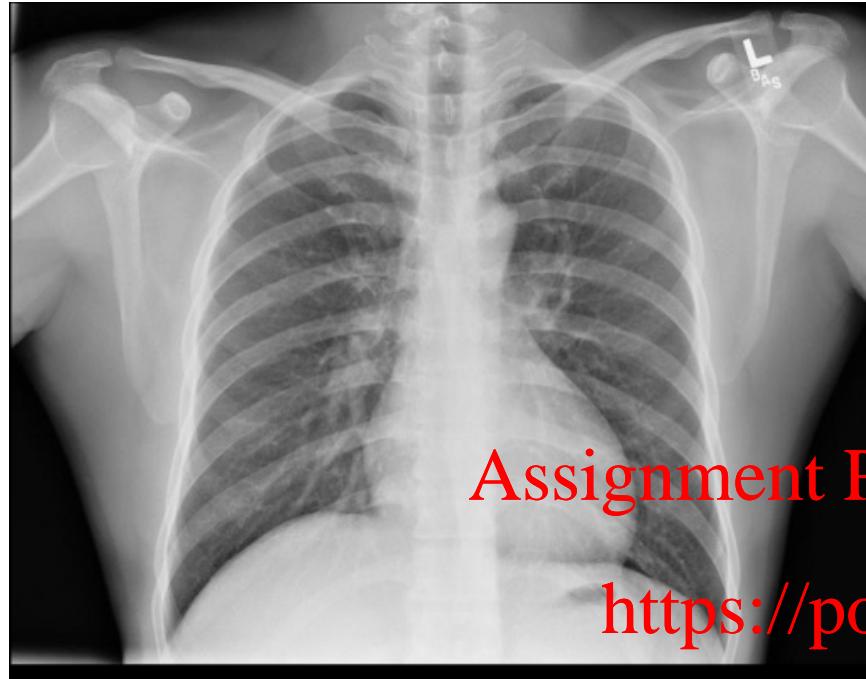
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*Supervision is
where the
action is...*

*Model differences overrated, and
supervision differences underrated.*



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We spent a year on this challenge

- Created large dataset of clinical labels
- Evaluated effect of label quality
- Work published in a *clinical journal*

J. Dunnmon, D. Yi, C. Langlotz, C. Re, D. Rubin, M. Lungren.
“Assessing Convolutional Neural Networks for Automated Radiograph Triage.” *Radiology*, 2019.

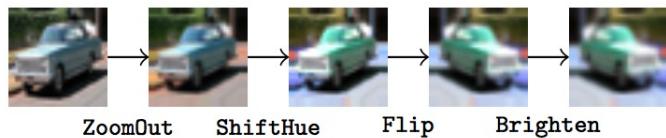
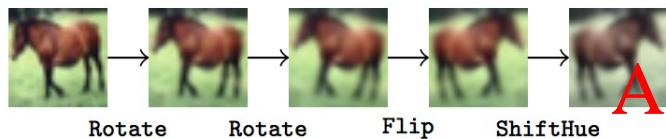
Model	Test Accuracy
BOVW + KSVM	0.88
AlexNet	0.87
ResNet-18	0.89
DenseNet-121	0.91

Often: Differences in models ~ 2-3 points.

Label quality & quantity > model choice.

Data augmentation by specifying invariances

Images



- Rotations
- Scaling / Zooms
- Brightness
- Color Shifts
- Etc...

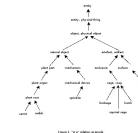
Text

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programs

$$P(w'_2 | w_1, w_0)$$

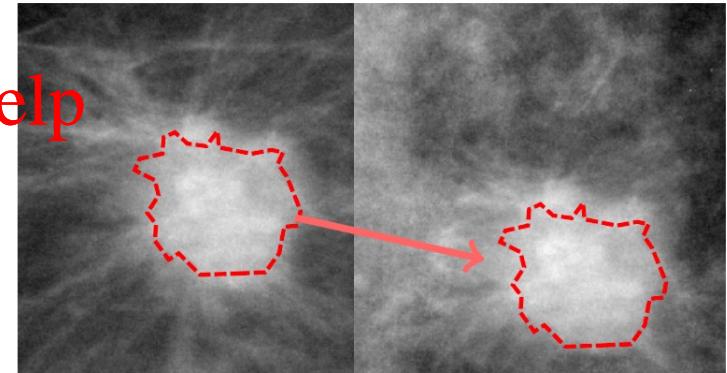
<https://powcoder.com>
Rachel writes code for WebCo.
E1 NN E2

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- Synonymy
- Positional Swaps
- Etc...

Medical



Domain-specific transformations. Ex:

1. Segment tumor mass
2. Move
3. Resample background tissue
4. Blend

How do we choose which to apply? In what order?

Simple Benchmarks: Data Augmentation is Critical



**Ex: 13.4 pt. avg. accuracy gain from data augmentation across top ten CIFAR-100 models—
*difference in top-10 models is less!***

Training Signal is key to pushing SotA

New methods for gathering signal leading the state of the art, lots of exciting ML progress here (SotA due to noisy teacher!)

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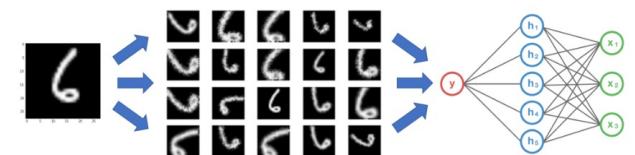
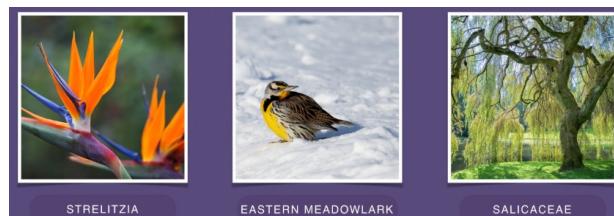
Google AI AutoAugment: <https://powcoder.com>
augmentation policies

- Augmentation Policies first in Ratner et al. NIPS'17



Facebook Hash tag weakly supervised pre-training

- Pre-train using a massive dataset with *hashtags*



Henry Ehrenberg (to: Washington)



Alex Ratner



Sharon Y. Li (to: Wisconsin)

Check out Sharon's series on hazyresearch.Stanford.edu



HOME PEOPLE

Automating the Art of Data Augmentation

Part I Overview

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<https://powcoder.com>

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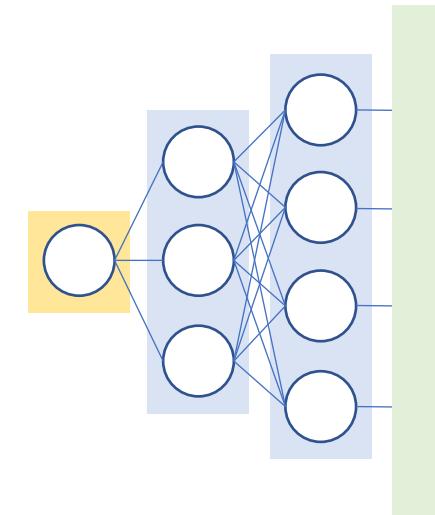
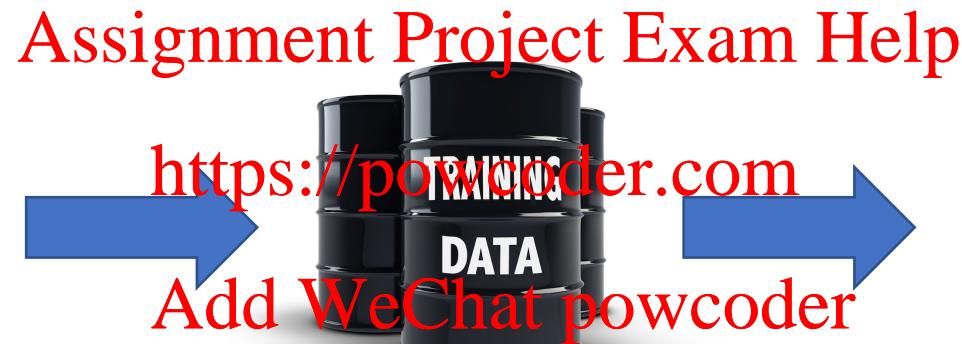
The Stanford AI Lab Blog



Sharon Y. Li
(to: Wisconsin)

<http://ai.stanford.edu/blog/data-augmentation/>

Training data: the new bottleneck



Slow, expensive, and static

Manual Labels



Programmatic Labels



Trade-off: programmatic labels are noisy...



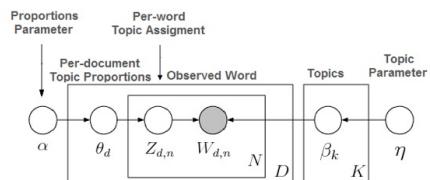
Snorkel: Formalizing Programmatic Labeling

Pattern Matching

```
regex.match(  
    r'{A} is caused by {B}'  
)
```

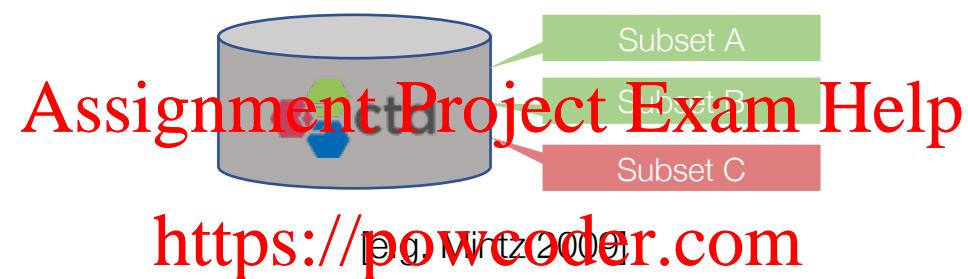
[e.g. Hearst 1992, Snow 2004]

Topic Models

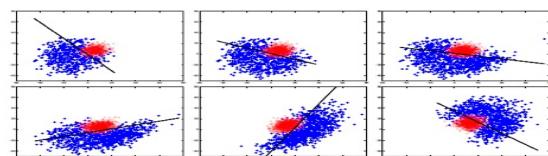


[e.g. Hingmire 2014]

Distant Supervision



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[e.g. Schapire 1998]

Augmentation



"Change abbreviate names, and replace..."

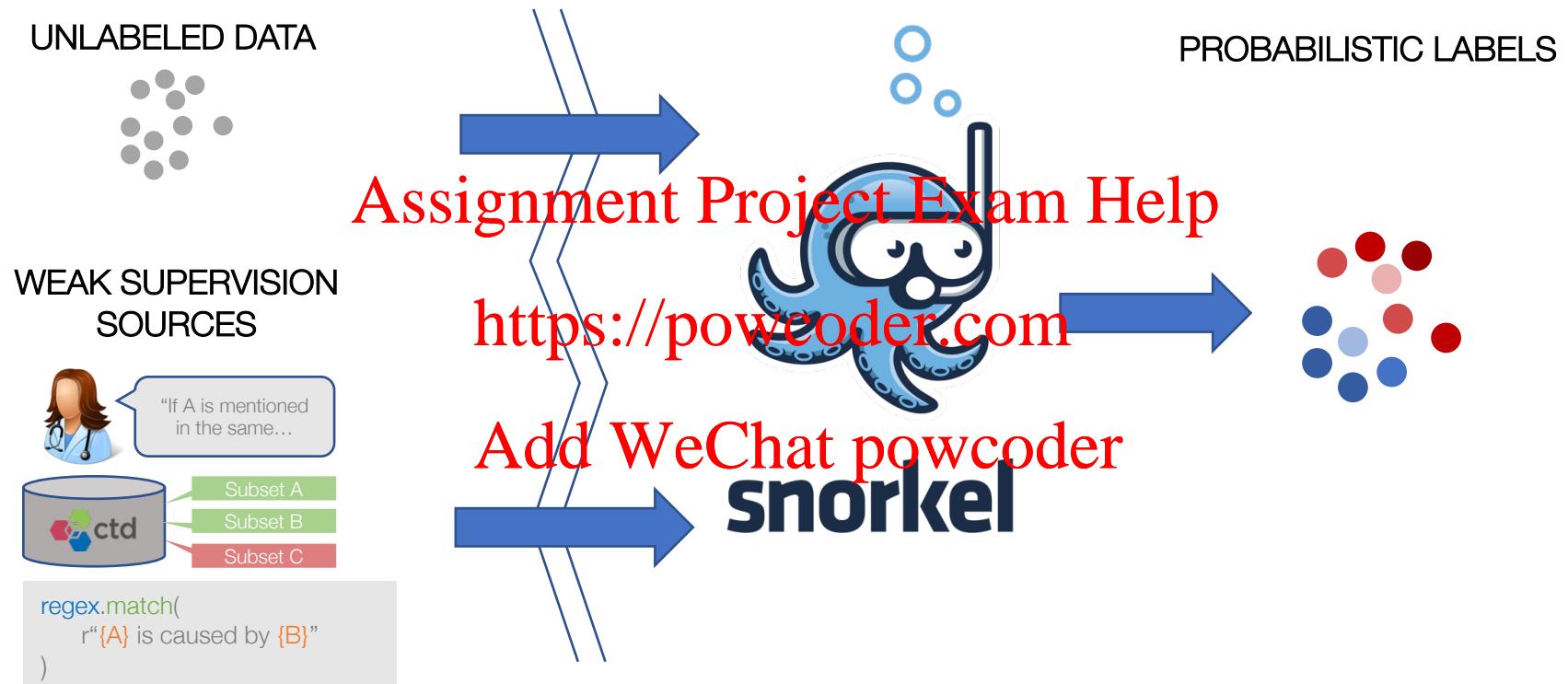
Crowdsourcing



[e.g. Dalvi 2013]

Observation: Weak supervision applied in *ad hoc* and isolated ways.

Snorkel: Formalizing Programmatic Labeling



Goal: Replace *ad hoc* weak supervision with a formal, unified, theoretically grounded approach for programmatic labeling



The Real Work



Stephen
Bach



Braden
Hancock



Braden
Hancock



Henry
Ehrenberg



Paroma
Varma

[Snorkel.org](https://powcoder.com)

Running Example: NER

PER:DOCTOR

Dr. Bob Jones is a specialist in
cardiomyopathy treatment,
leading the cardiology
division at Saint Francis.

<https://powcoder.com>

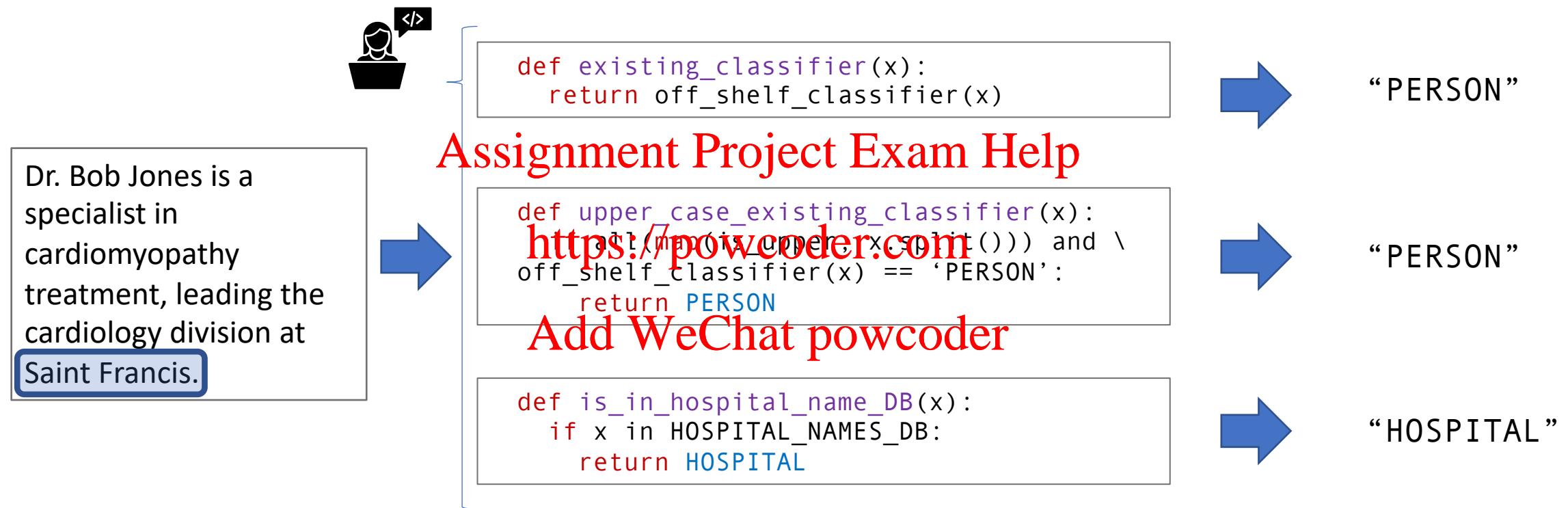
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ORG:HOSPITAL

*Let's look at labeling
“Person” versus
“Hospital”*

Goal: Label training data using *weak supervision* strategies for these tasks

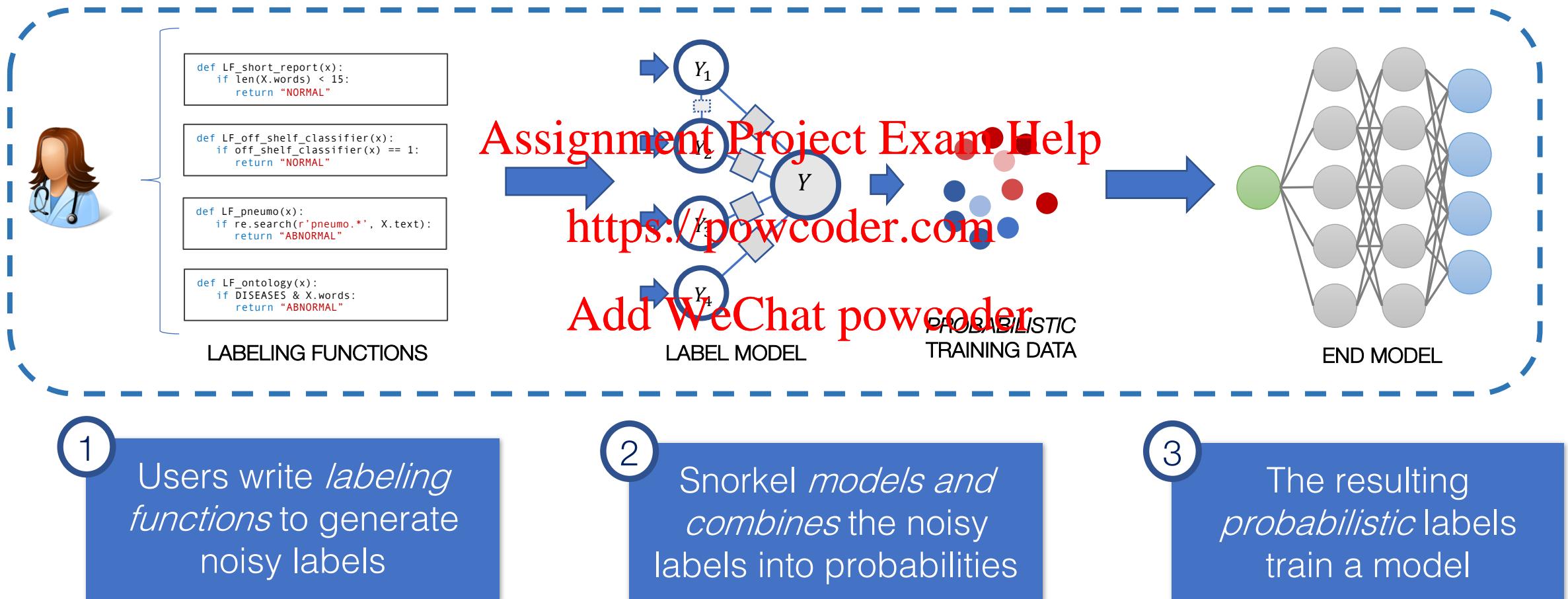
Weak Supervision as Labeling Functions



**Problem: These noisy sources
*conflict and are correlated***



The Snorkel Pipeline



KEY IDEA: Probabilistic training point carries accuracy. No hand labeled data needed.

People use it...



snorkel

[Http://snorkel.org](http://snorkel.org)

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<https://powcoder.com>

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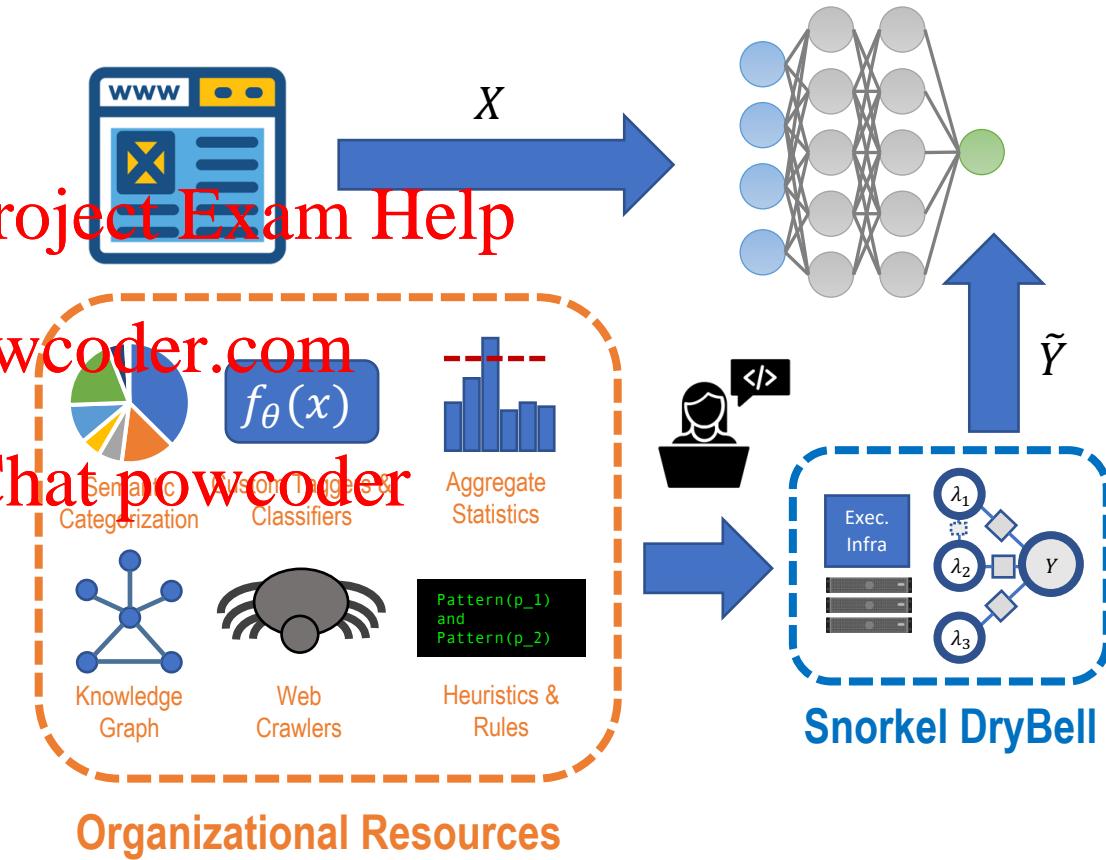
“Snorkel DryBell” collaboration with Google Ads. Bach et al. SIGMOD19.

Used in production in many industries, startups, and other tech companies!

Collaboration Highlight: Google + Snorkel

- *Snorkel DryBell* is a production version of Snorkel focused on:

- Using *organizational knowledge resources* to train ML models
- Handling *web-scale* data
- Non-servable to servable feature transfer.



Thank you, Google!
Even best funded teams...

[Bach et. al., SIGMOD 2019]

Maybe you have used it?

Overton: A Data System for Monitoring and Improving
Machine-Learned Products

Christopher Ré
Apple

Feng Niu
Apple

Pallavi Gudipati
Apple

Charles Srisuwananukorn
Apple

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<https://powcoder.com>
**Migrating a Privacy-Safe Information Extraction System to
a Software 2.0 Design**

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Ying Sheng
Google
Mountain View, CA, USA
yingsheng@google.com

Nguyen Vo
Google
Mountain View, CA, USA
nguyenvo@google.com

James B. Wendt
Google
Mountain View, CA, USA
jwendt@google.com

Sandeep Tata
Google
Mountain View, CA, USA
tata@google.com

Marc Najork
Google
Mountain View, CA, USA
najork@google.com

**Leveraging Organizational Resources to Adapt Models to
New Data Modalities**

Sahaana Suri[†], Raghuveer Chanda, Neslihan Bulut, Pradyumna Narayana, Yemao Zeng
Peter Bailis[†], Sugato Basu, Girija Narlikar, Christopher Ré[†], Abishek Sethi
Google, Stanford[†]



It has changed use real systems...

Resourcing	Error Reduction	Amount of Weak Supervision
High	65% (2.9×)	80%
Medium	82% (5.6×)	96%
Medium	72% (3.6×)	98%
Low	40% (1.7×)	99%

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A couple of highlights

- Used by multiple teams with good error reduction over production.
- Take away: many systems are almost entirely weak supervision based.

Weak Supervision in Science & Medicine

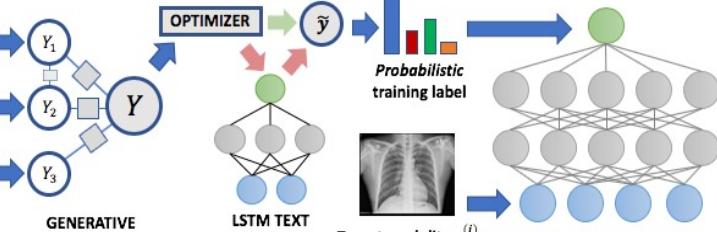
Cross-Modal Weak Supervision

"Indication: Chest pain. Findings: No focal consolidation or pneumothorax."

Auxiliary modality $x_a^{(i)}$

```
def LF_pneumo(x):
    if search('pneumo.*', X):
        return "ABNORMAL"
def LF_ontology(x):
    if DISEASES & X.words:
        return "ABNORMAL"
def LF_short_report(x):
    if len(X.words) < 15:
        return "NORMAL"
```

LABELING FUNCTIONS (LFs)

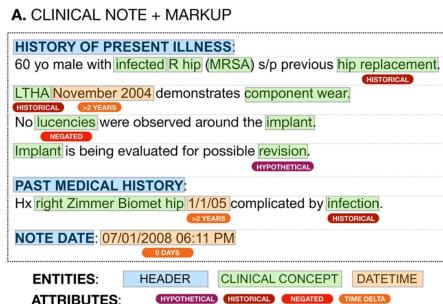


J. Dunnmon et al., "Cross-Modal Data Programming Enables Rapid Medical Machine Learning," 2020.

Blog: <http://hazyresearch.stanford.edu/ws4science>

Text & Extraction

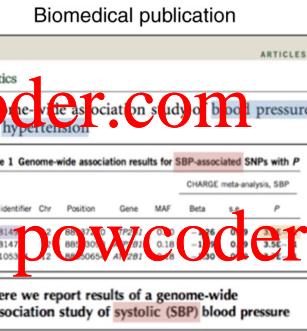
A. Callahan et al.,
NPJ Dig Med, 2020



B. LABELING FUNCTION DEFINITIONS

```
def LF1_contiguous_entities(c):
    v = len(between_words(c)) == 0
    return TRUE if v else ABSTAIN
def LF2_historical_attr(c):
    v = has_historical_attribute(c)
    return FALSE if v else ABSTAIN
def LF3_reject_section(c):
    h1 = get_section_header(c)
    v = h1.is_reject_header()
    return FALSE if v else ABSTAIN
def LF4_negated(c):
    v = NegEx.is_negated(c)
    return FALSE if v else ABSTAIN
```

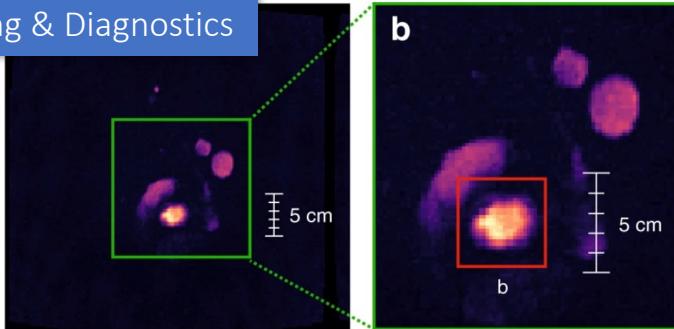
FALSE: -1 ABSTAIN: 0 TRUE: 1



Variant	rs2681492
Simple phenotype	Hypertension Blood pressure
Detailed phenotype	Systolic
p-value	3.0e-11
Source	PMID: 19430479, Tbl. 1

V. Kuleshov et al.,
Nat Comms, 2019

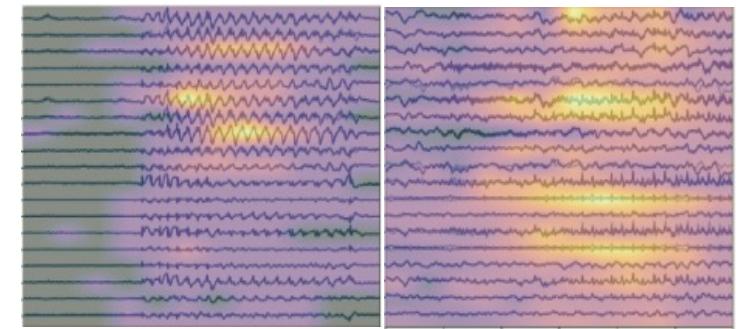
Imaging & Diagnostics



J. Fries et al., Nat Comms, 2019



J. Dunnmon et al., Radiology, 2019



K. Saab et al., NPJ Dig Med, 2020

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High-Level Related Work

LUDWIG



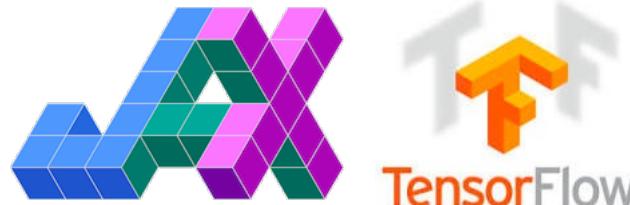
snorkel

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Snorkel DryBell: A Case Study in Deploying
Weak Supervision at Industrial Scale



PyTorch



Core ML

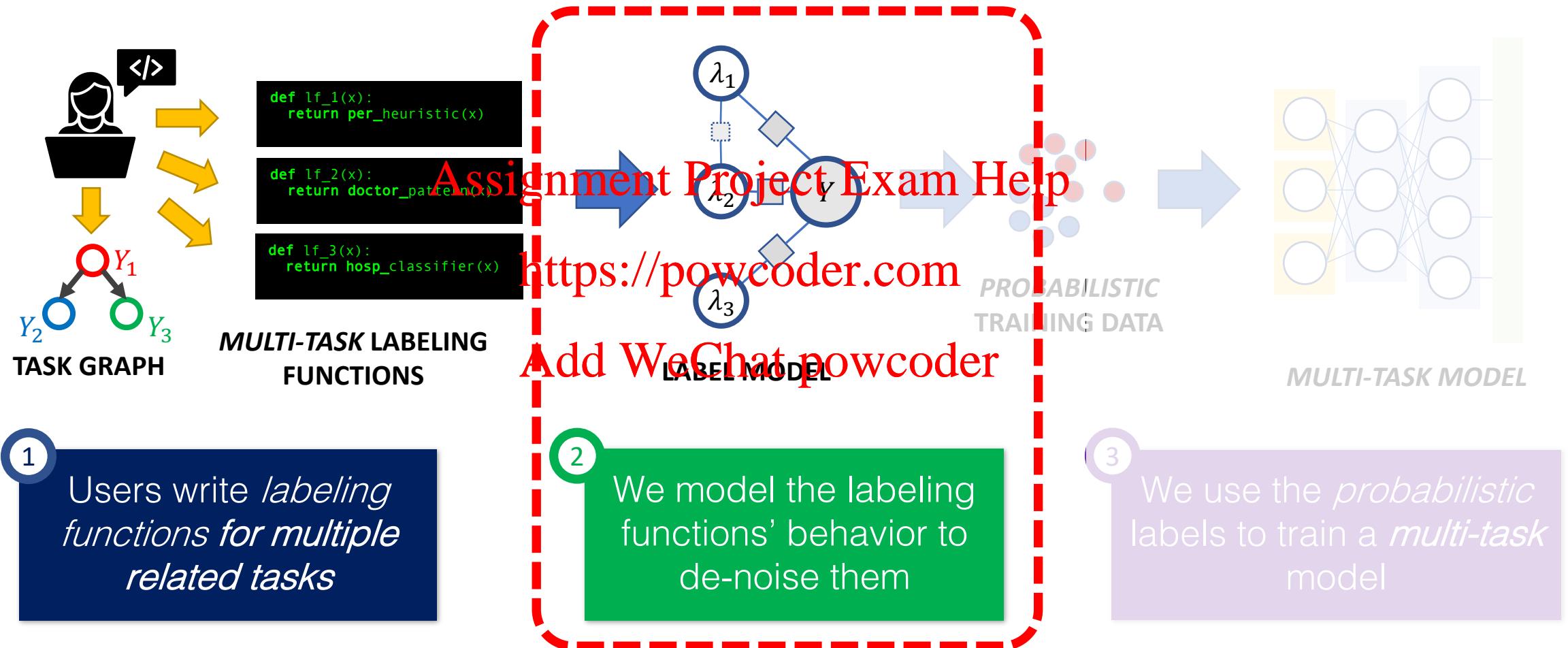


Alex ~~Ratner~~ Assignment Project Exam Help

(to Washington) <https://powcoder.com> (to Wisconsin)

Let's look under the hood and take a peak at
some math (to the whiteboard soon..)
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The Snorkel Pipeline



How can we do anything without the ground truth labels?

Model as Generative Process

*Later: We will define
what this picture means
precisely.*

```
def existing_classifier(x):  
    return off_shelf_classifier(x)
```

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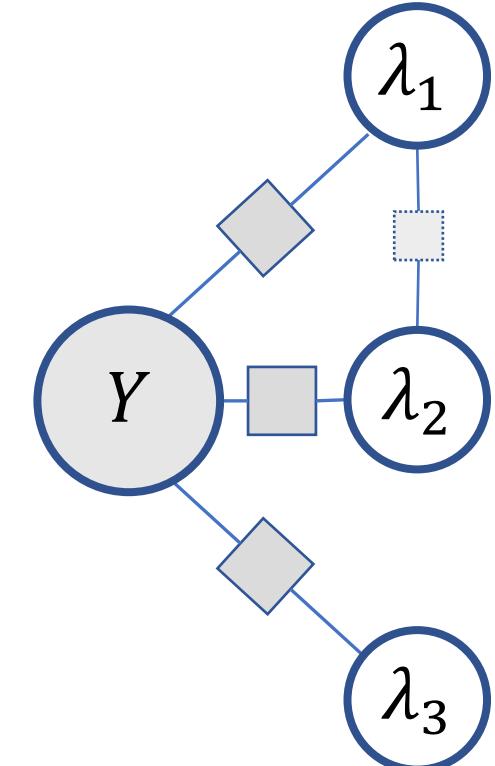
```
def upper_case_existing_classifier(x):  
    if all(map(is_upper, x.split())) and \  
        off_shelf_classifier(x) == 'PERSON':  
        return PERSON
```

<https://powcoder.com>
“PERSON”

```
def is_in_hospital_name_DB(x):  
    if x in HOSPITAL_NAMES_DB:  
        return HOSPITAL
```

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“HOSPITAL”



**How to learn the parameters of this model
(accuracies & correlations) without Y ?**

Intuition: Learn from the Overlaps

Sources.

```
def existing_classifier(x):  
    return off_shelf_classifier(x)
```

```
def upper_case_existing_classifier(x):  
    if all(map(is_upper, x.split(' '))) and  
        off_shelf_classifier(x) == 'PERSON':  
        return PERSON
```

```
def is_in_hospital_name_DB(x):  
    if x in HOSPITAL_NAMES_DB:  
        return HOSPITAL
```

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x_1

"PERSON"

"PERSON"

"HOSPITAL"

x_2

"PERSON"

"HOSPITAL"

"HOSPITAL"

...

Key idea: We observe agreements (+1) and disagreements (-1) on many points! (More later!)