Direct Uncertainty Prediction for Medical Second Opinions

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Poster #246

Human Expert Disagreements

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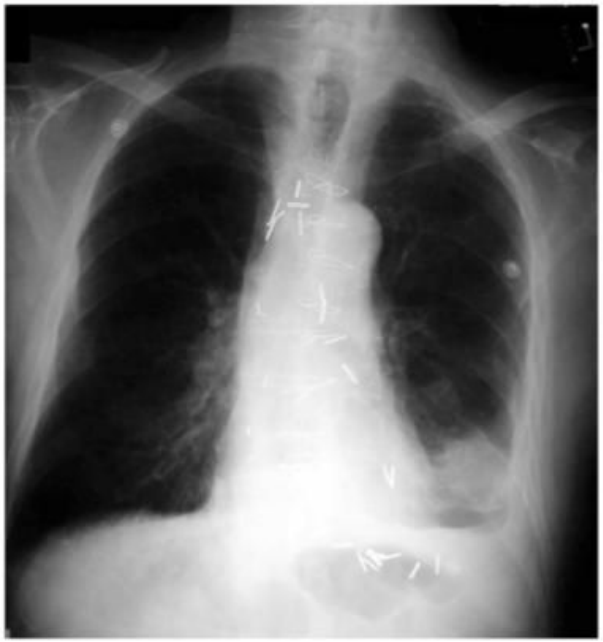

No follow up exam

Follow up exam

Doctor Disagreements

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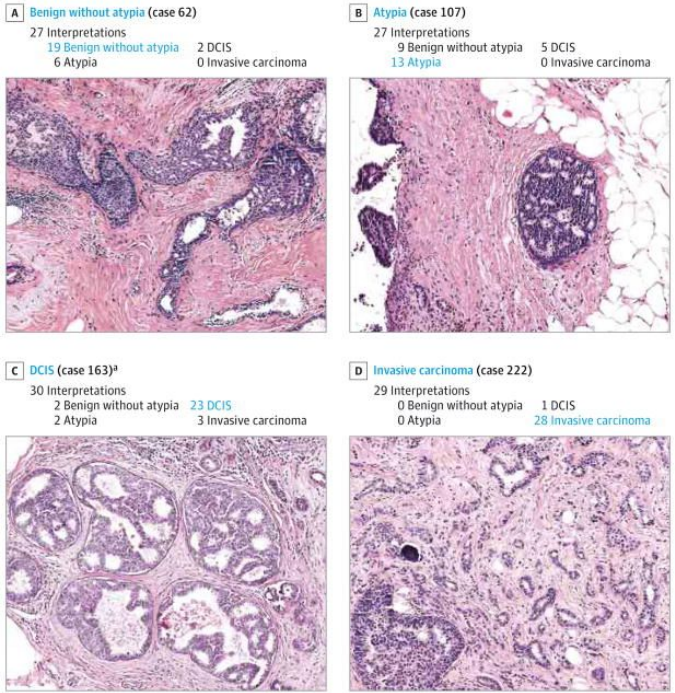
Diagnostic Concordance Amongst Pathologists Interpreting Breast Biopsy Specimens, UW School of Medicine, JAMA, 2015



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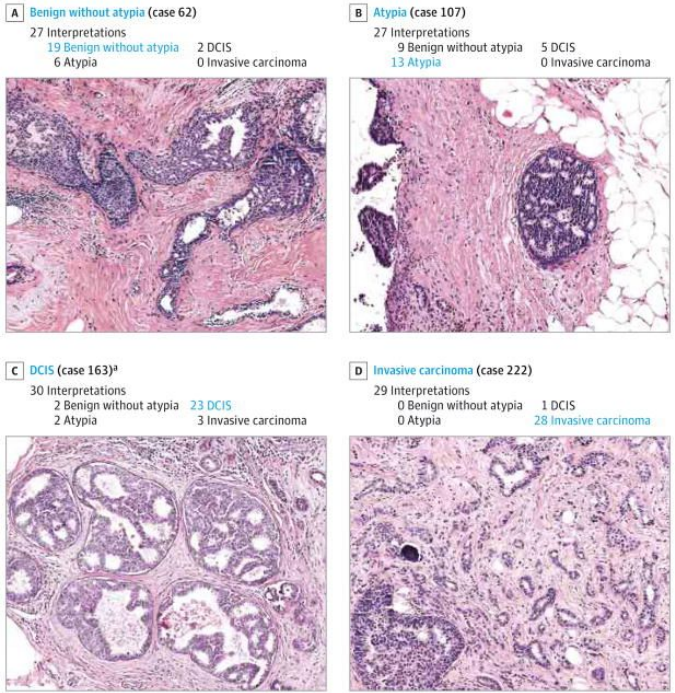
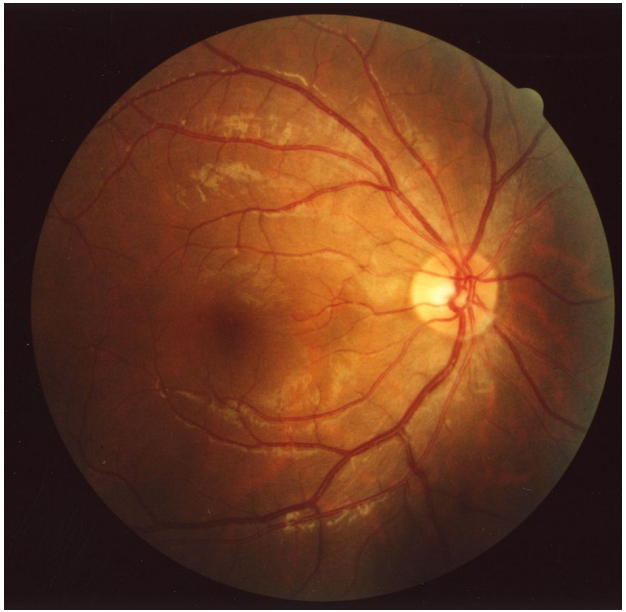


- Agreement between individual pathologist grade and a panel consensus score on ~240 breast biopsies, 6900 individual case diagnoses
- **25% disagreement** between pathologists and consensus

Doctor Disagreements

Ophthalmology: Diagnosis from Fundus Photographs

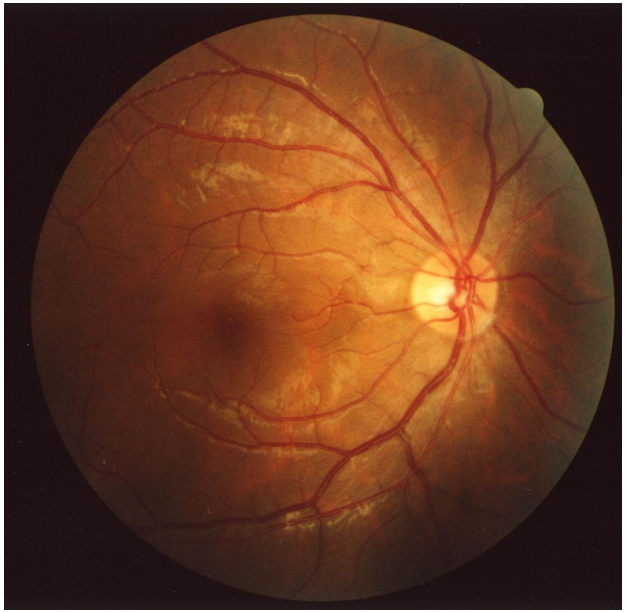


Grade 2: Mild Diabetic Retinopathy

Grade 3: Moderate Diabetic Retinopathy

The Source of Disagreements

Ophthalmology: Diagnosis from Fundus Photographs

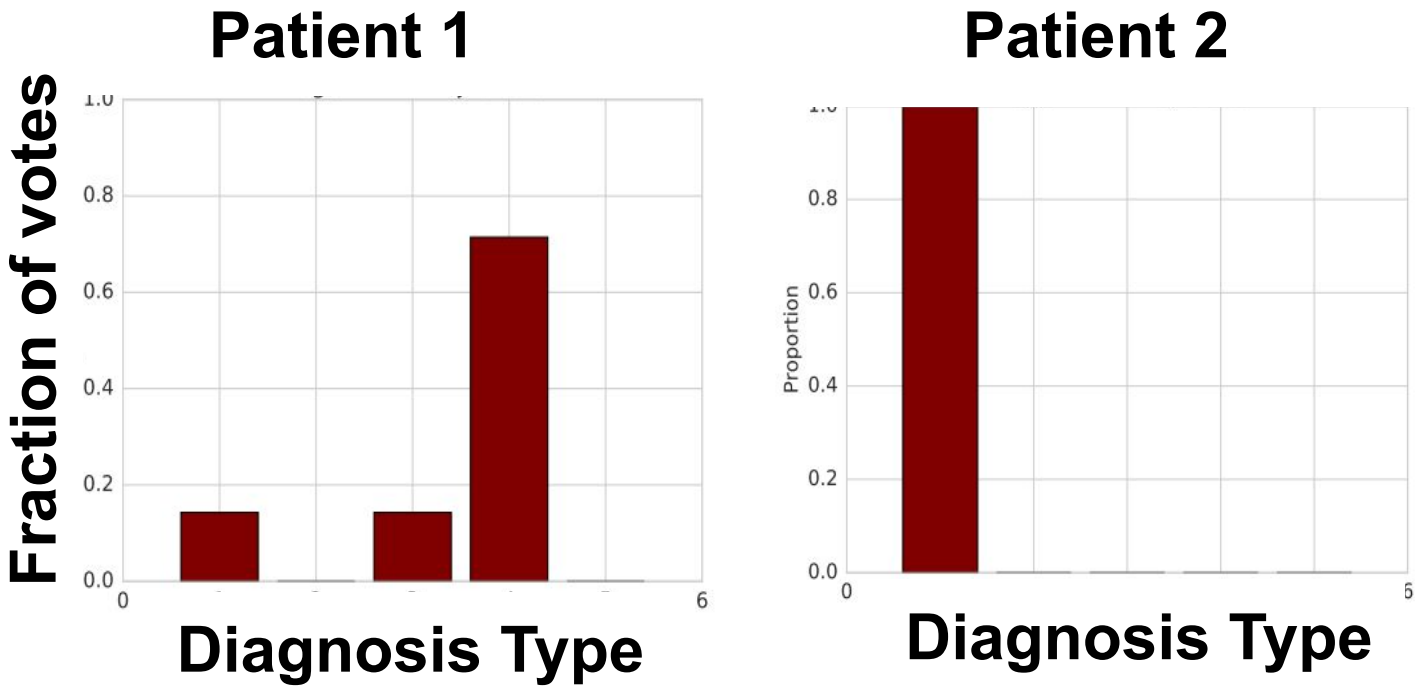


Grade 2: Mild Diabetic Retinopathy

Grade 3: Moderate Diabetic Retinopathy

Random Mistakes?

The Source of Disagreements



ML for Doctor Disagreement Prediction

Given input (image) x, predict the amount of disagreement. Flag patients for *medical second opinions.*

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Training data: x_i, with multiple labels $y^{(i)}_1,...,y^{(i)}_k$ (different doctors) I.e. (x_i, $\mathbf{p}_i$), $\mathbf{p}_i$ grade distribution, target $U(\mathbf{p}_i)$ (e.g. U() = entropy)

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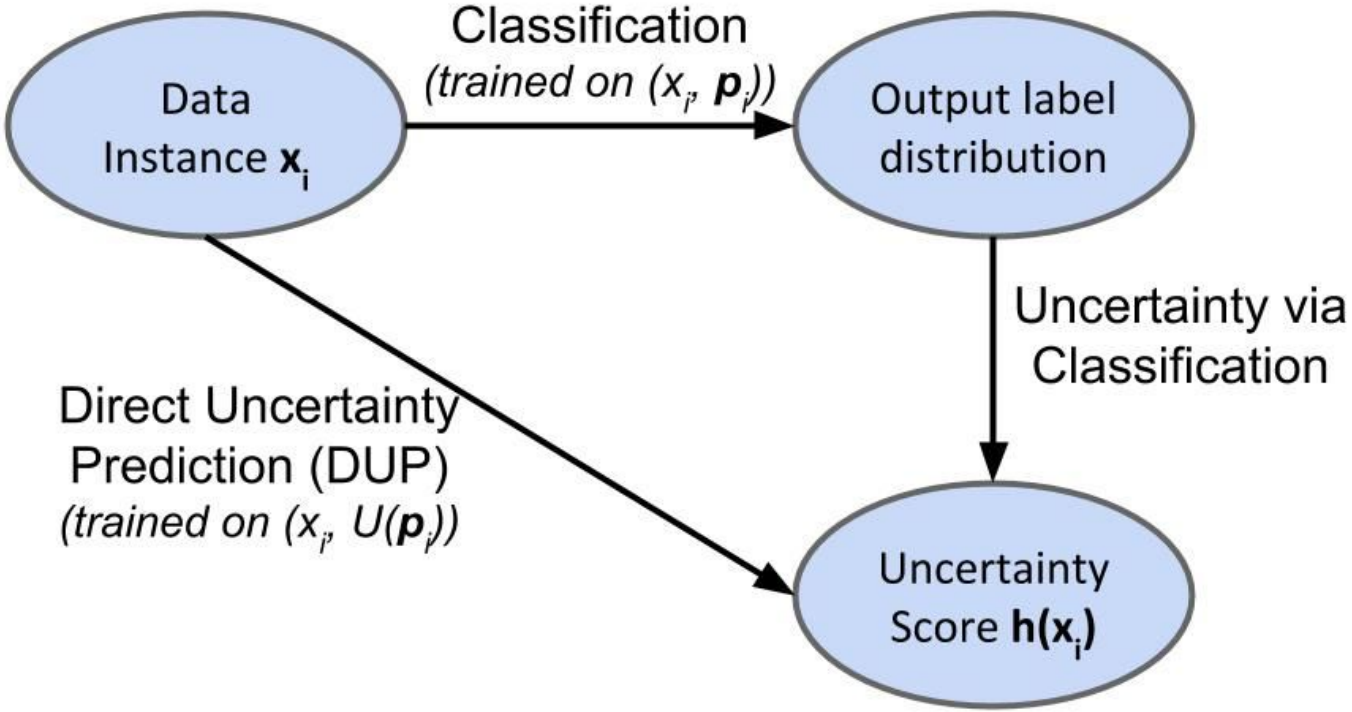
1) **Uncertainty Via Classification (UVC)**: (i) train *classifier* on empirical distribution of labels (x_i, $\mathbf{p}_i$) (ii) postprocess with U()

2) **Direct Uncertainty Prediction (DUP):** directly predict scalar uncertainty score (x_i, $U(\mathbf{p}_i)$)

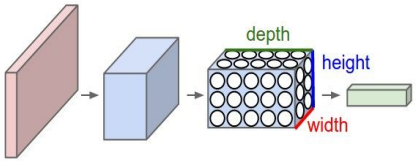
Direct Uncertainty Prediction



Direct Uncertainty Prediction

Hidden information:

61 (age) F (gender) medical history



Direct Uncertainty Prediction

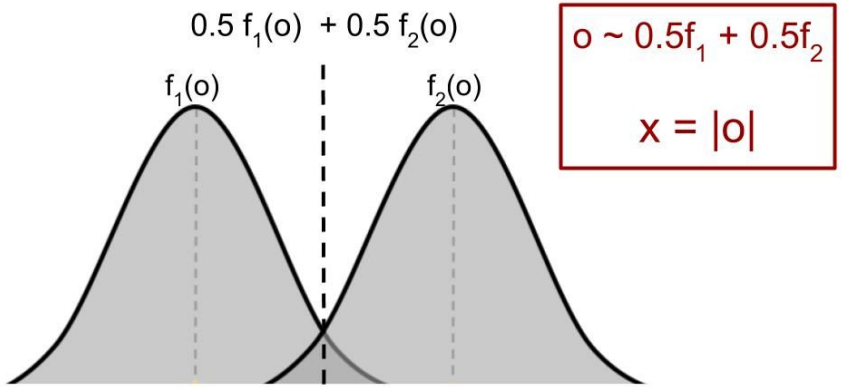
$$h_{dup}(x) = \int U(\mathbb{E}[\mathbf{Y}|O = o]) f_O(o|g(O) = x)$$

$$h_{uvc}(x) = U\left(\int \mathbb{E}[\mathbf{Y}|O = o] f_O(o|g(O) = x)\right)$$

Theorem: DUP gives an unbiased estimate of true uncertainty

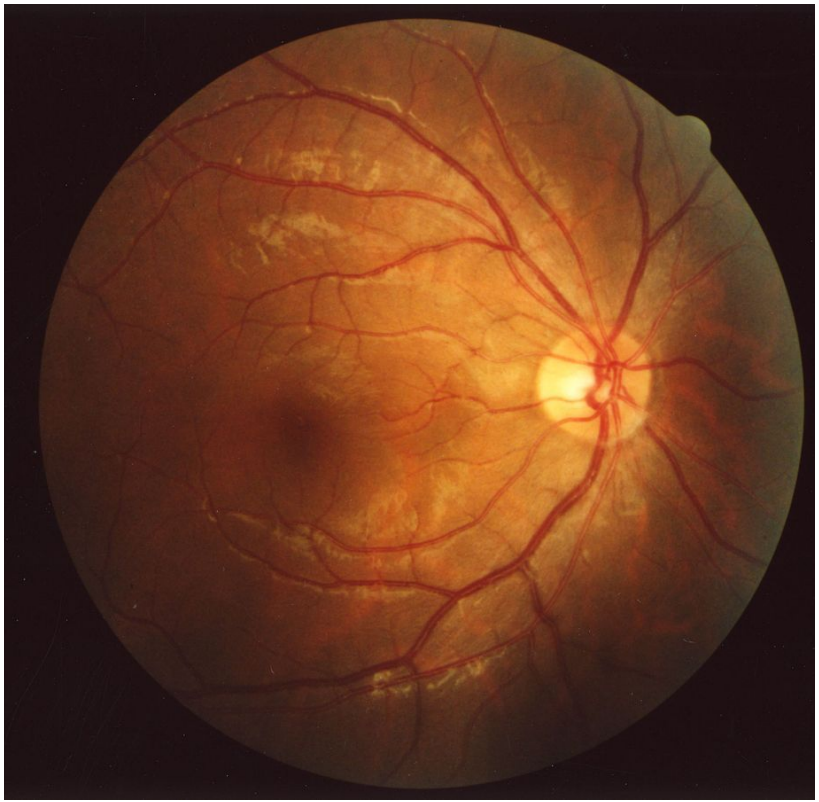
Empirical Results: Synthetic Examples

Mixture of Gaussians



SVHN and CIFAR-10: Image Blurring Application

Large Scale Medical Application



Diabetic Retinopathy (DR)
5 class scale:

1 None
2 Mild

Referable

3 Moderate
4 Severe
5 Proliferative

Large Scale Medical Application

Task		Model Type	Performance (AUC)
Variance Prediction	UVC	Histogram-E2E	70.6%
Variance Prediction	UVC	Histogram-PC	70.6%
Variance Prediction	DUP	Variance-E2E	72.9%
Variance Prediction	DUP	Variance-P	74.4%
Variance Prediction	DUP	Variance-PR	74.6%
Variance Prediction	DUP	Variance-PRC	**74.8%**
Disagreement Prediction	UVC	Histogram-E2E	73.4%
Disagreement Prediction	UVC	Histogram-PC	76.6%
Disagreement Prediction	DUP	Disagree-P	**78.1%**
Disagreement Prediction	DUP	Disagree-PC	**78.1%**
Variance Prediction	DUP	Disagree-PC	73.3%
Disagreement Prediction	DUP	Variance-PRC	77.3%

Poster #246: Direct Uncertainty Prediction for Medical Second Opinions

Large Scale Medical Application

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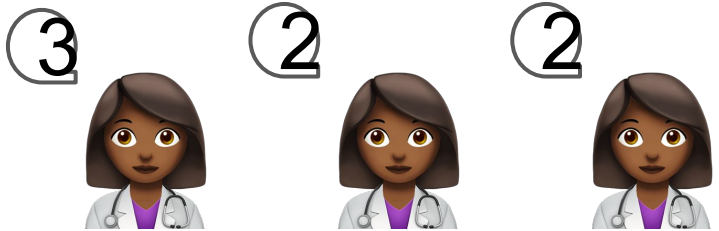
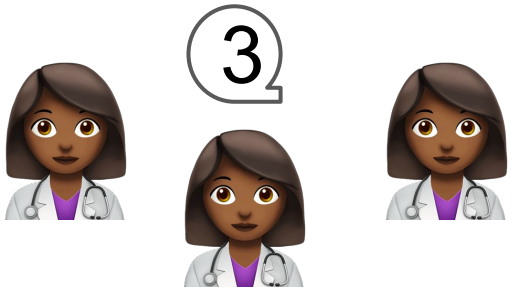
Small Gold Standard Evaluation Set

Individual Grades by Specialists



Single, Consensus, Adjudicated Grade



	Model Type	Majority	Median	Majority = 1	Median = 1	Referable
UVC	Histogram-E2E-Var	78.1%	78.2%	81.3%	78.1%	85.5%
UVC	Histogram-E2E-Disagree	78.5%	78.5%	80.5%	77.0%	84.2%
UVC	Histogram-PC-Var	77.9%	78.0%	80.2%	77.7%	85.0%
UVC	Histogram-PC-Disagree	79.0%	78.9%	80.8%	79.2%	84.8%
DUP	Variance-PR	80.0%	79.9%	83.1%	80.5%	85.9%
DUP	Variance-PRC	79.8%	79.7%	82.7%	80.2%	85.9%
DUP	Disagree-P	**81.0%**	80.8%	**84.6%**	**81.9%**	**86.2%**
DUP	Disagree-PC	80.9%	**80.9%**	84.5%	81.8%	**86.2%**