**EXPERT ENSEMBLES ARE EVERYWHERE**

Human ensemble ("crowd") - Labeling subjective phenomena

Machine classifier ensemble - State of the art systems in ML applications

**GLOBALLY VARIANT LOCALLY CONSTANT MODEL**

- Classical assumption – all experts are equally reliable
- Better – each expert has different reliability

$$P(y = k) = \pi_a$$

**BAYES OPTIMAL FUSION RULE FOR GVLC MODEL**

- Simple plurality fusion:
  $$\hat{y} = \arg \max_{k} \sum_{j} y'_k$$
  where $$y'_k = 1$$ if $$y'_j = k$$ and 0 otherwise

- Variable expert reliability model:
  $$\hat{y}_{MAP} = \arg \max_k \left[ \log \pi_a + \sum_{j} \sum_{k} y'_j \log A^i(k, k) \right]$$

- GVLC model-based fusion:
  $$\hat{y}_{MAP} = \arg \max_k \left[ P(z = m | y = k; \Theta_m) P(y = k | x; \Lambda) \right]$$
  $$= \arg \max_k \left[ \prod_{j=1}^{k} A^j(k, k)^{y'_j} \right]$$

- Non-linear fusion rule, other rules special cases

**CREATING A DIVERSE MAXENT ENSEMBLE**

Collaborators – Abhinav Sethy, Bhuvana Ramabhadran, IBM T. J. Watson Research Lab

"You don’t understand anything until you learn it more than one way" – Marvin Minsky

- Common view – ad-hoc training of diverse models
- Bagging/boosting – no control on diversity

**Train diverse models in a principled way with control?**

- Focus – Maximum Entropy Model Ensemble:
  $$P_x(y | x) = \frac{\exp(\sum_{i=1}^{n} \lambda_i f_i(x, y))}{\sum_{y} \exp(\sum_{i=1}^{n} \lambda_i f_i(x, y))} Z(x)$$

- $$x$$ - input, $$y$$ - output label, $$\{\lambda_i\}_{i=1}^n$$ - parameters

- ML estimation:
  $$\Lambda' = \arg \max_{\Lambda} \sum_{m=1}^{N} \sum_{x,y} \lambda_i f_i(x, y, z) - \log Z(x) = \arg \max_{\Lambda} L(\Lambda)$$

- Introduce diversity constraint w.r.t. reference model $$Q$$:
  $$L_{\text{div}}(\Lambda) = L(\Lambda) - aD(P_x, Q_x)$$

- Intuitive diversity scores – KL divergence and negative posterior cross-correlation

**IN PROGRESS**

- Training arbitrary diverse classifier ensembles
- Quantifying diversity benefit in arbitrary expert ensembles
- Linking diversity with gradient boosting

---


This research was supported by NSF, DARPA and NIH