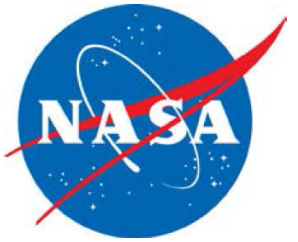
National Aeronautics and Space Administration



Using Ensemble Decisions and Active Selection to Improve Low-Cost Labeling for Multi-View Data

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July 2, 2011
ICML 2011 Workshop on Combining Learning Strategies for Reducing Label Cost
Bellevue, WA

Classification of Sensor Network Data

- Node-level classification (in situ)
- Each node collects unique “view”
- Limited availability of labeled data
- Continuous stream of unlabeled data
- Nodes may communicate

Combining Learning Strategies

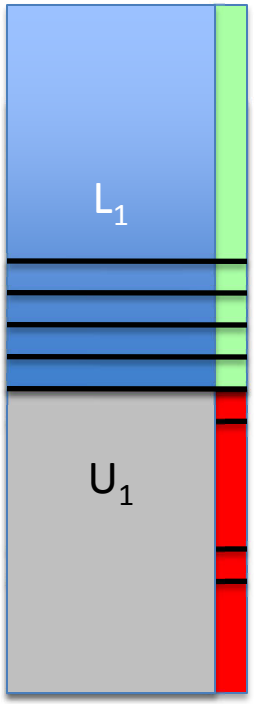
Example Selection	Labeling	Learning Strategy
High-confidence	Low-cost (self)	Bootstrapping Co-training
Low-confidence	High-cost (oracle)	Active learning
Low-confidence	Low-cost (ensemble)	?

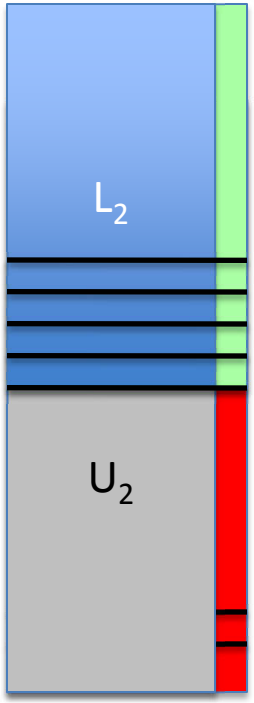
Co-training

- Multi-view
- Semi-supervised
- Self-labels

Co-training[1]

- Each learner classifies its unlabeled pool
- Each learner selects its most confident predictions
- All selected examples are moved to L_1 and L_2



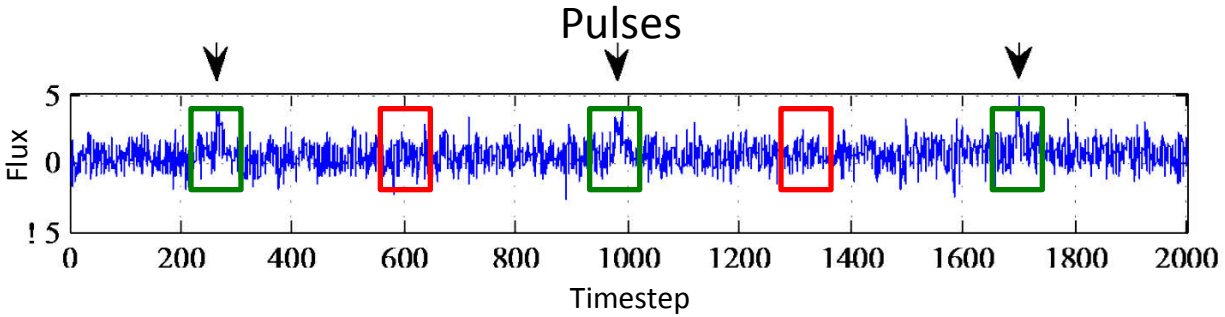


[1] Blum and Mitchell, Combining Labeled and Unlabeled Data with Co-training, COLT,1998

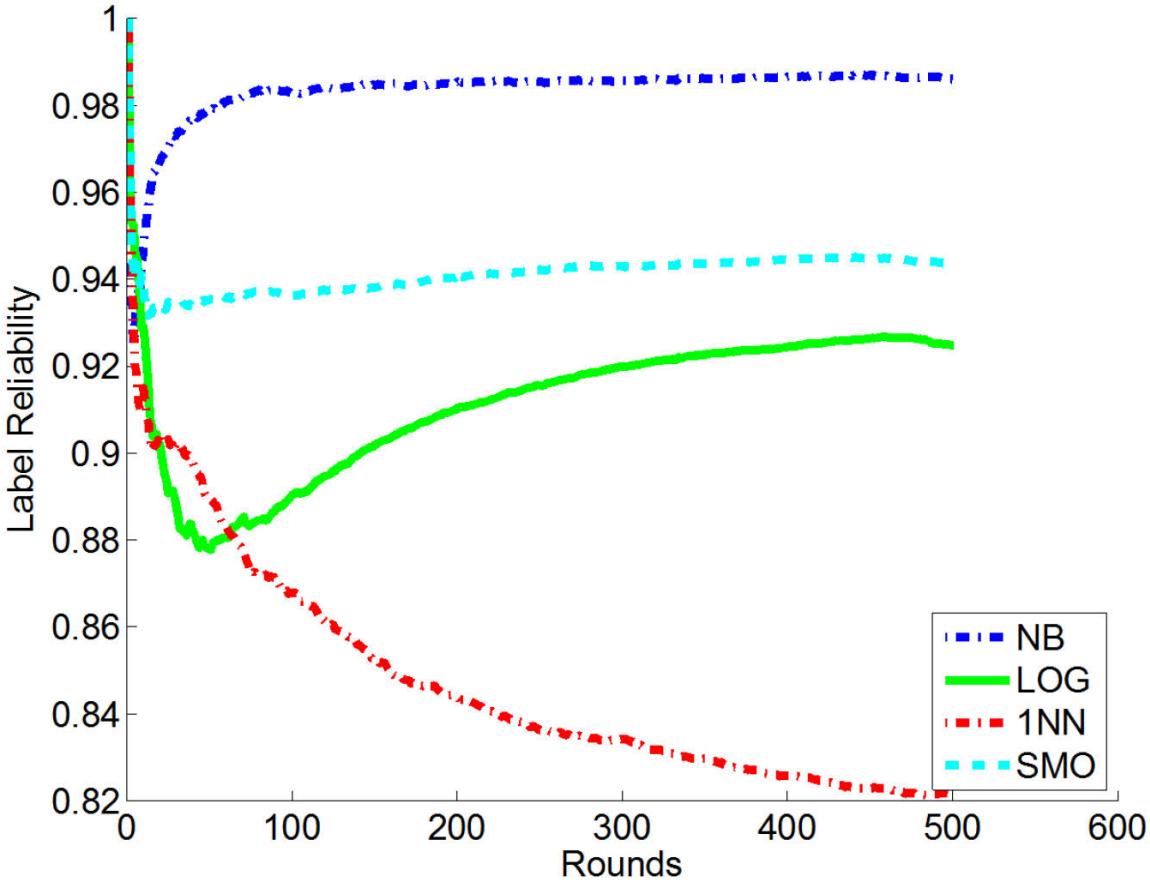
Very Long Baseline Array (VLBA) Data

- Geographically dispersed antennas
- Time series observations of pulsar PSR B0329+54
- 21 observations per example
- Classify pulse/non-pulse (680 pos, 680 neg)
- Created 4-, 6- and 9-view data sets. Results shown on 4-view data set

One antenna (view)

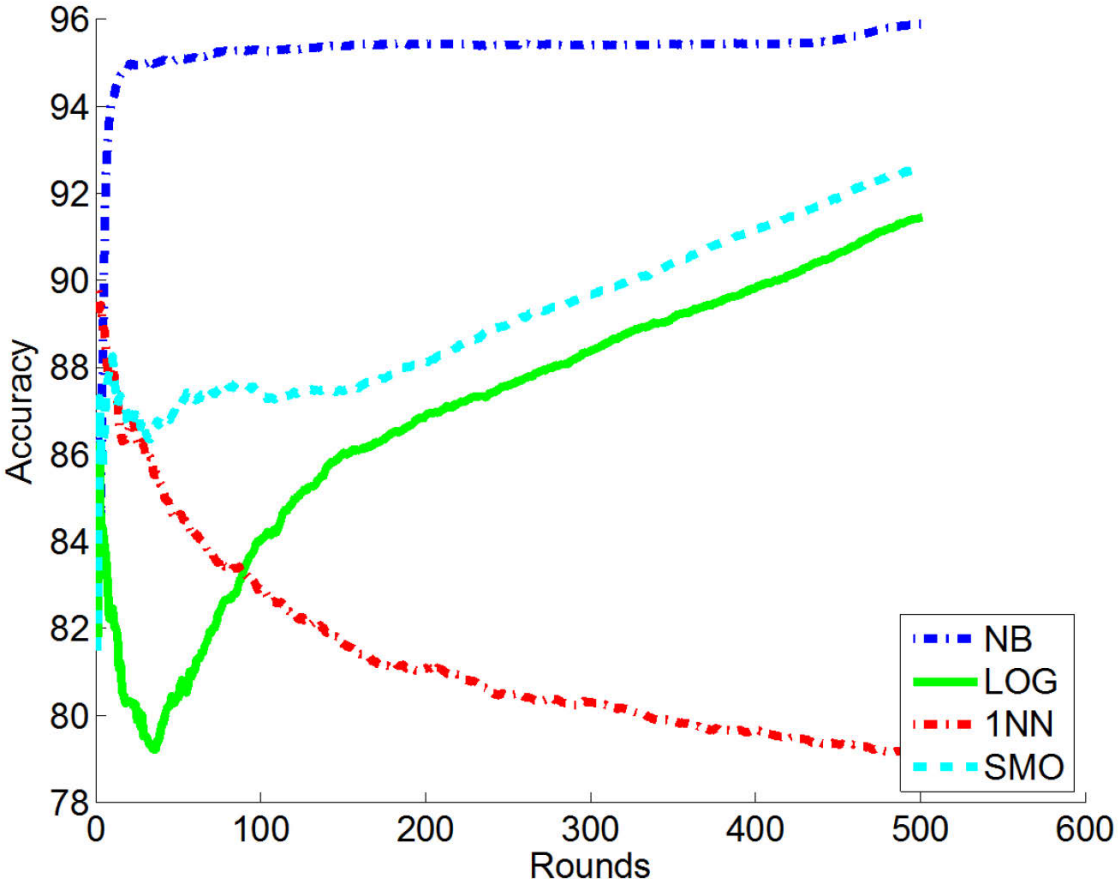


Co-training Produces Unreliable Labels



- Self-labeling introduces label noise
- Sensitive to base learner
- Noted by Pierce & Cardie, 2001

Co-training Produces Unreliable Labels



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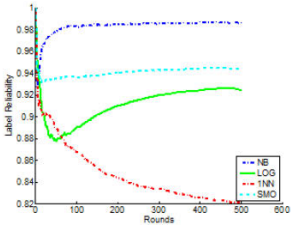
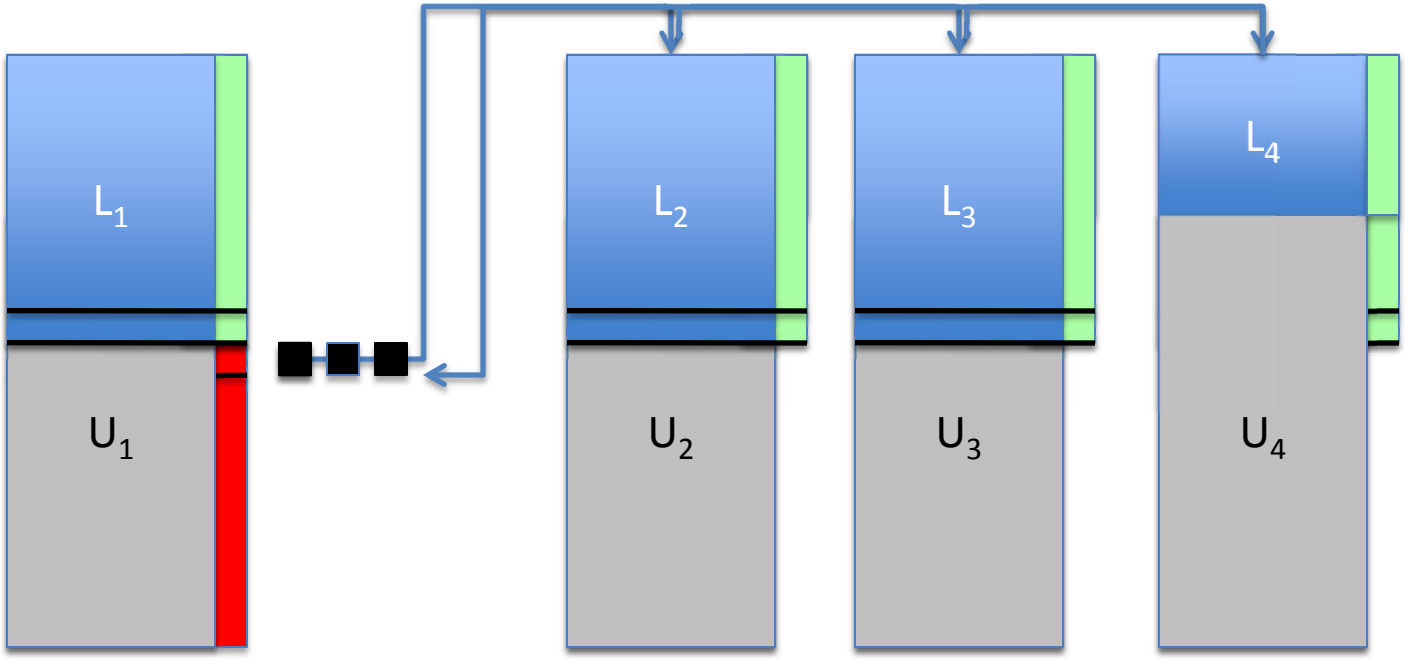


Talk Outline

- Low-cost ways to improve label reliability?
- Can we combine low-cost labeling with low-confidence example selection?

Multi-view Ensemble Labeling

- Learner classifies U_1, and selects an example
- Learner queries the other learners for a label
- Learner receives responses, and unifies them
- Example is added to L_1, L_2, L_3 and L_4

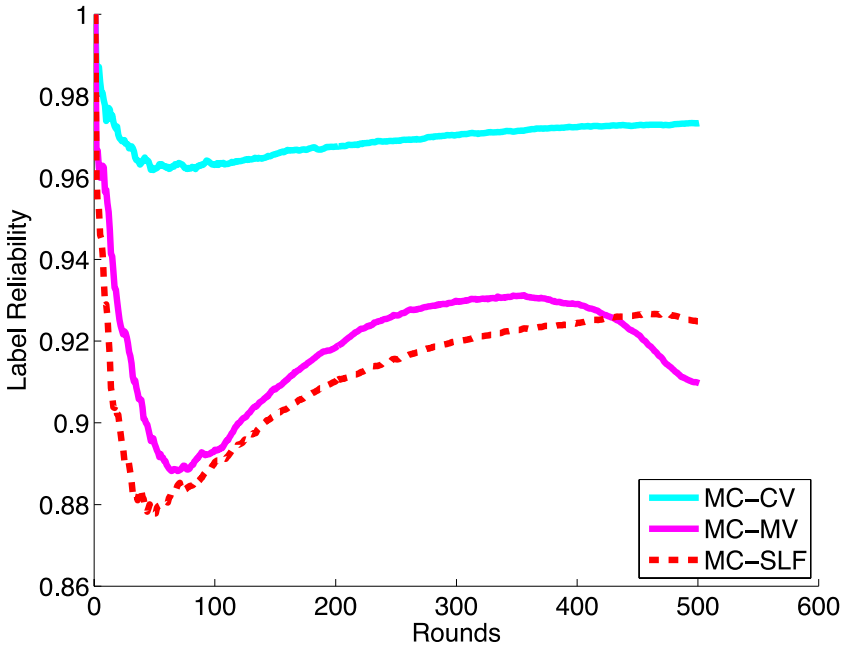


Ensemble Labeling

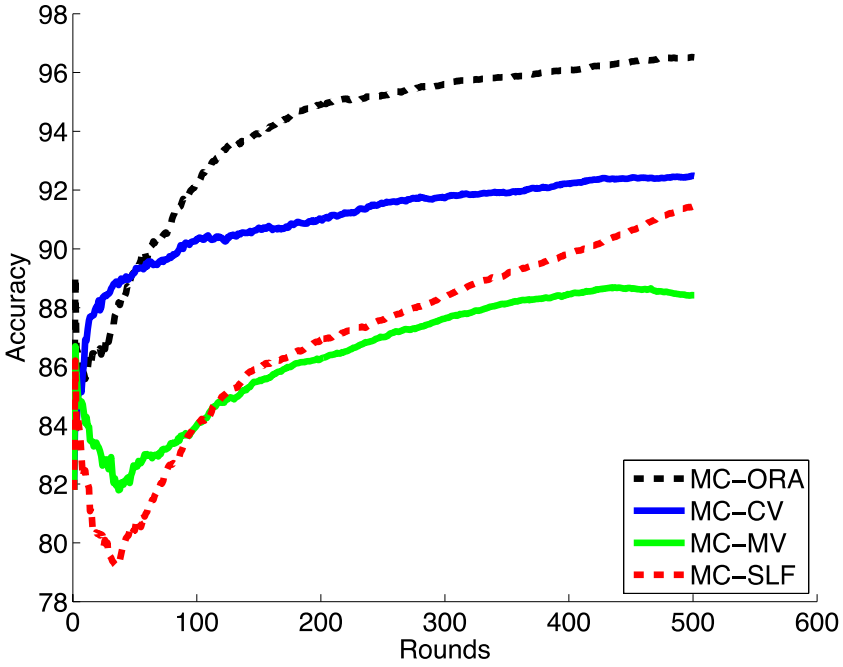
- Strategies for unifying neighbor predictions
- Abstain if cannot unify prediction with high confidence
- Majority Vote
  - Choose prediction with most votes
  - Abstain if at least half the ensemble did not make this prediction
- Consensus Vote
  - Choose unanimous prediction, otherwise abstain

Ensemble Labeling

Label Reliability



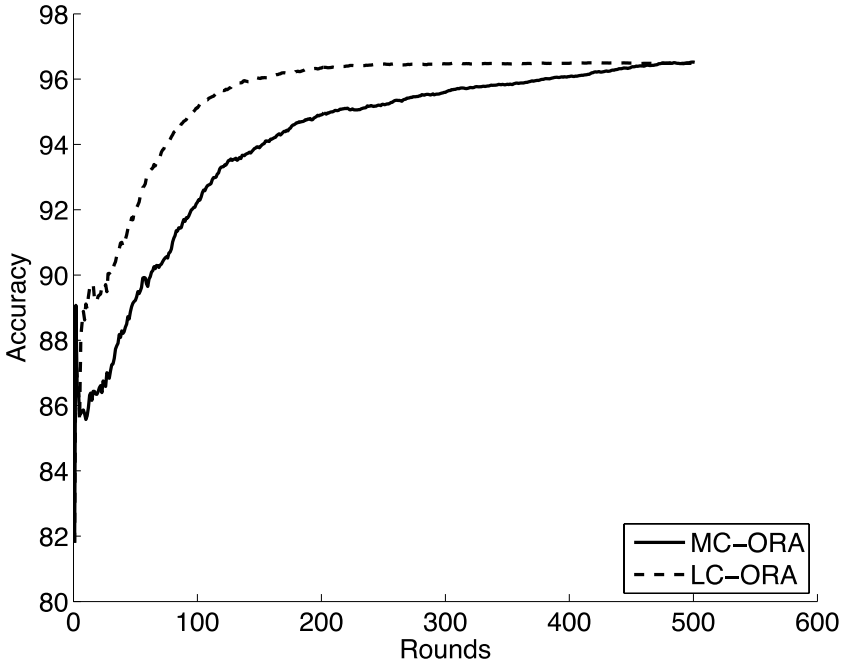
Test Set Accuracy



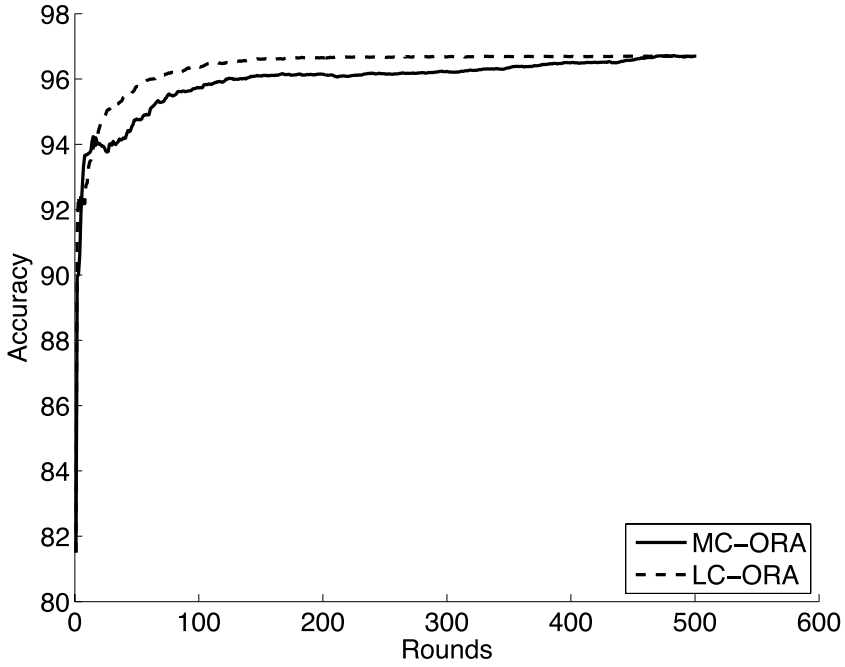
Logistic Regression

Low Confidence (LC) Example Selection with Oracle Labeling

Logistic Regression

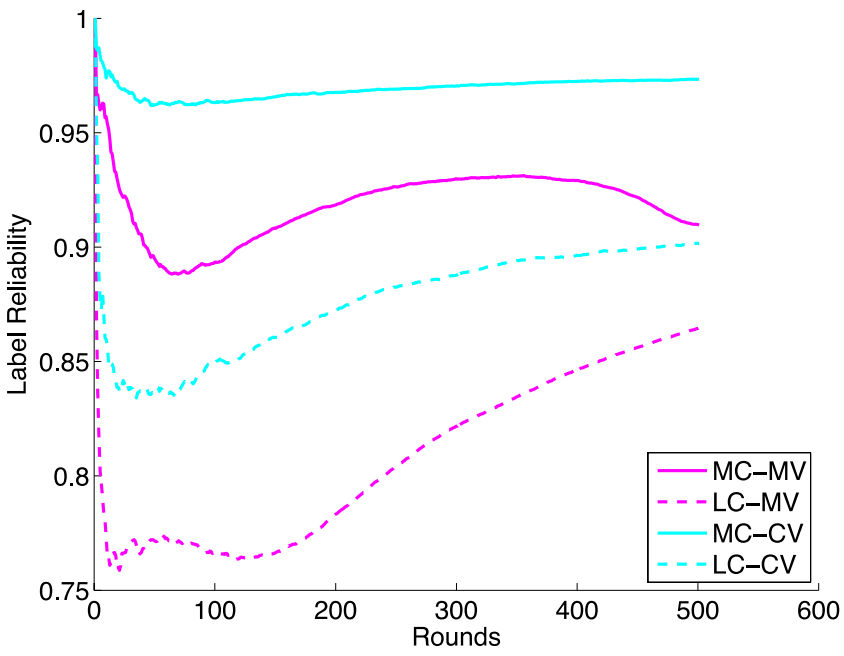


SVM

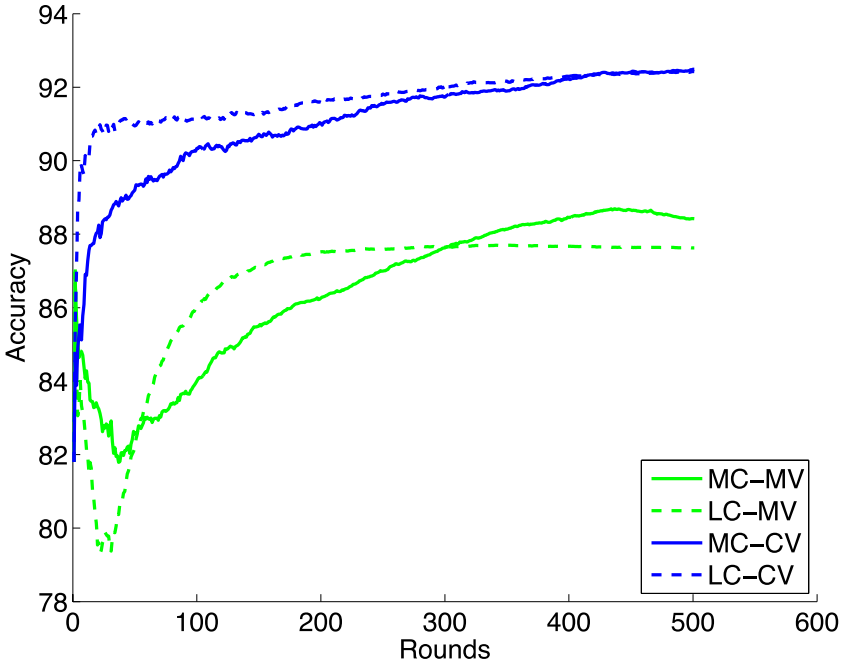


Pairing Low-Confidence Example Selection with Low-Cost Labeling

Label Reliability



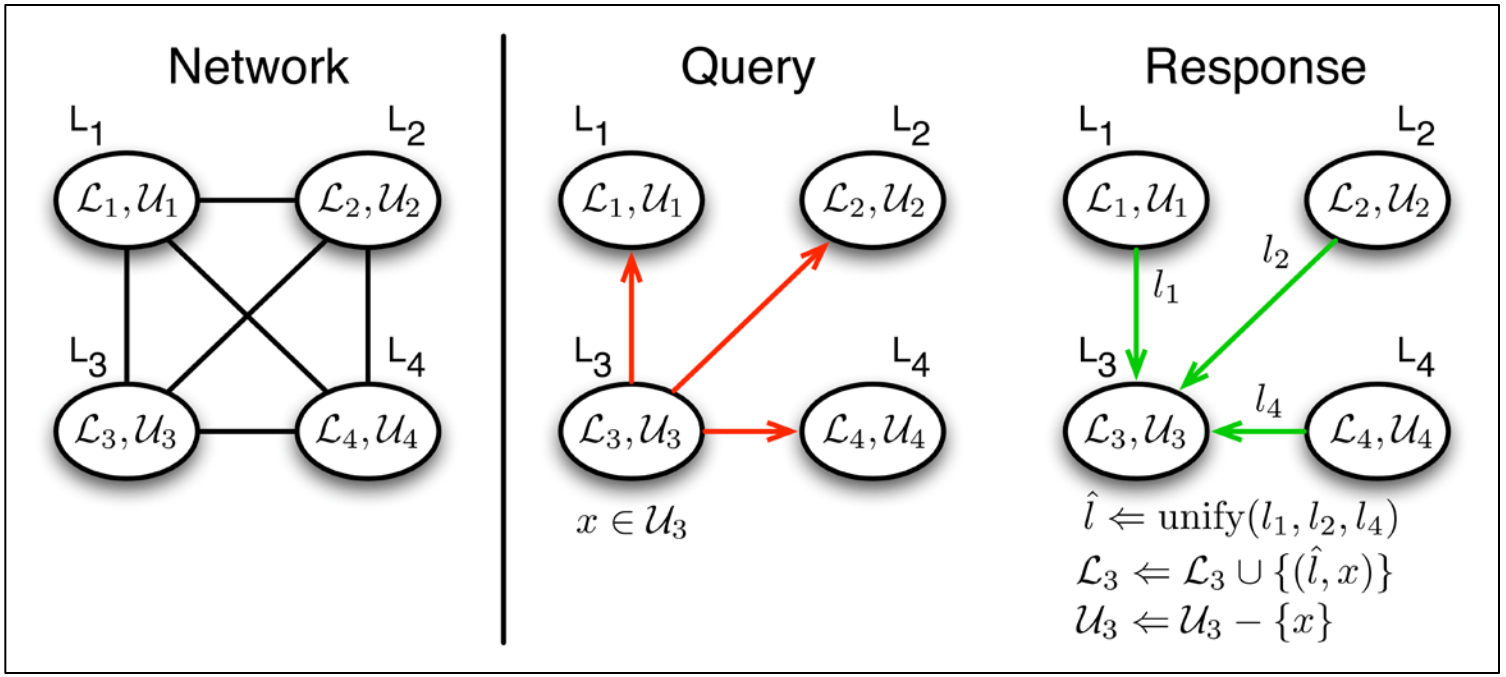
Accuracy



Logistic Regression – p-values fail significance tests!

Collaborative Learning

- Each node of sensor network contains a classifier
- Classifier initialized with small amount of labeled data
- Classifier labels incoming data
- Collaborative learning learners to collaborate via queries to its nearest neighbors for examples and labels



Future Work

- Experimental results on 4-, 6-, 9-view VLBA data, and two 4-view data sets created from UCI repository
- Improve abstention policies => improve label reliability
- Goal: Confirm low-cost labeling and low-confidence example selection are compatible