# An Ensemble of Face Recognition Algorithms for Unsupervised Expansion of Training Data

Anthony Clark
anthonyclark@missouristate.edu

Jeff Dale
jdale@ieee.org

Missouri State

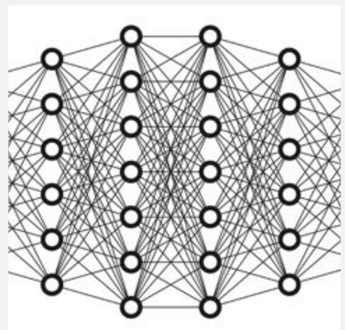
# Motivation

### Security

Ability to unlock personal devices with faces

### Smart Surveillance

Send alerts when unknown persons appear on premises



### Deep Learning

On big data, deep learning approaches are unparalleled

### Small Data

Big data is nice, but difficult to obtain

### Ensemble Learners

The herd often makes better decisions than the individual

# Problem

How accurate can face recognition methods be with the smallest possible training data?

## Small Training

- One known face per subject given
- Many subjects possible
- Goals:
  - Augment training set with unlabeled faces from testing set.
  - Do not introduce incorrect labels to training set

## Large Testing

- Many unlabeled faces needed
- So that we can validate our method
- Caveat:
  - All subjects in testing must appear in training

# Our Approach

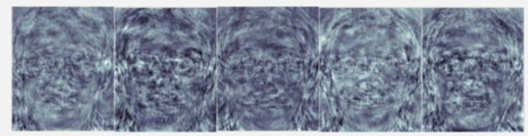
We used four classical algorithms in a face recognition ensemble and created a novel voting strategy

## Eigenfaces

Uses PCA to create “Eigenfaces”

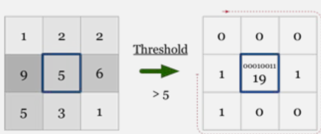
## Fisherfaces

Like Eigenfaces, but uses LDA over PCA



## Local Binary Pattern Histograms

Examines relative intensities around each pixel

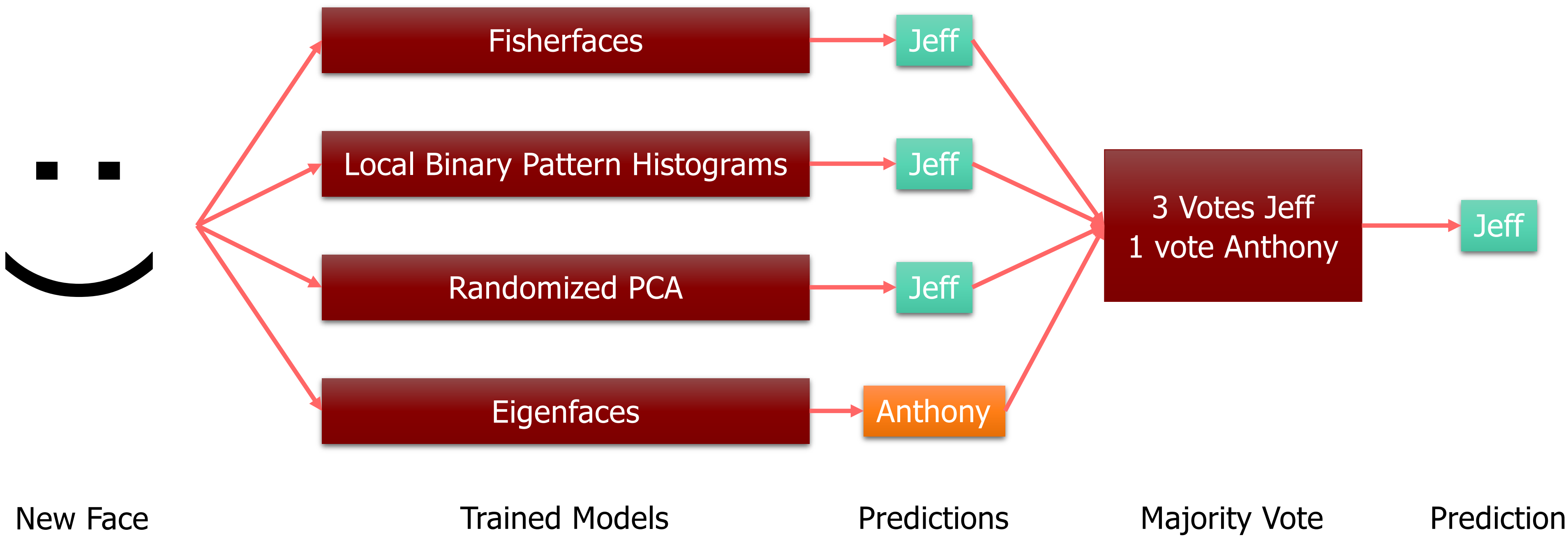



## Randomized PCA

Like Eigenfaces, but computes PCA differently

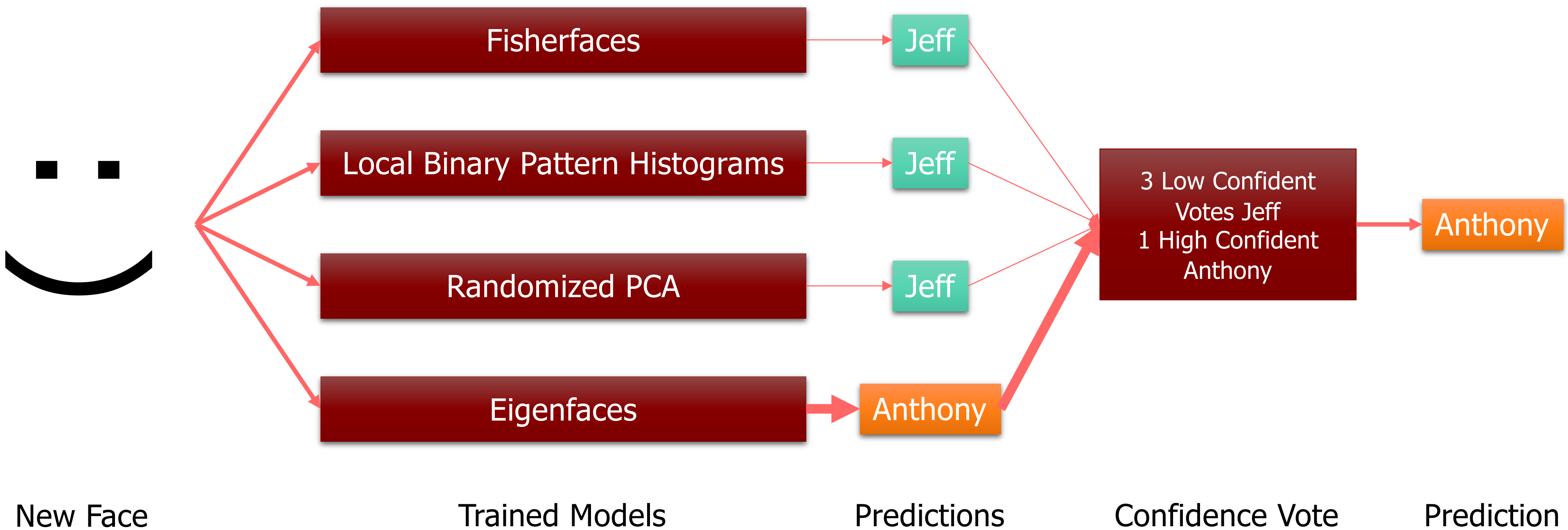
# Common Ensemble Method

Many ensemble method use majority voting



# Proposed Ensemble Method

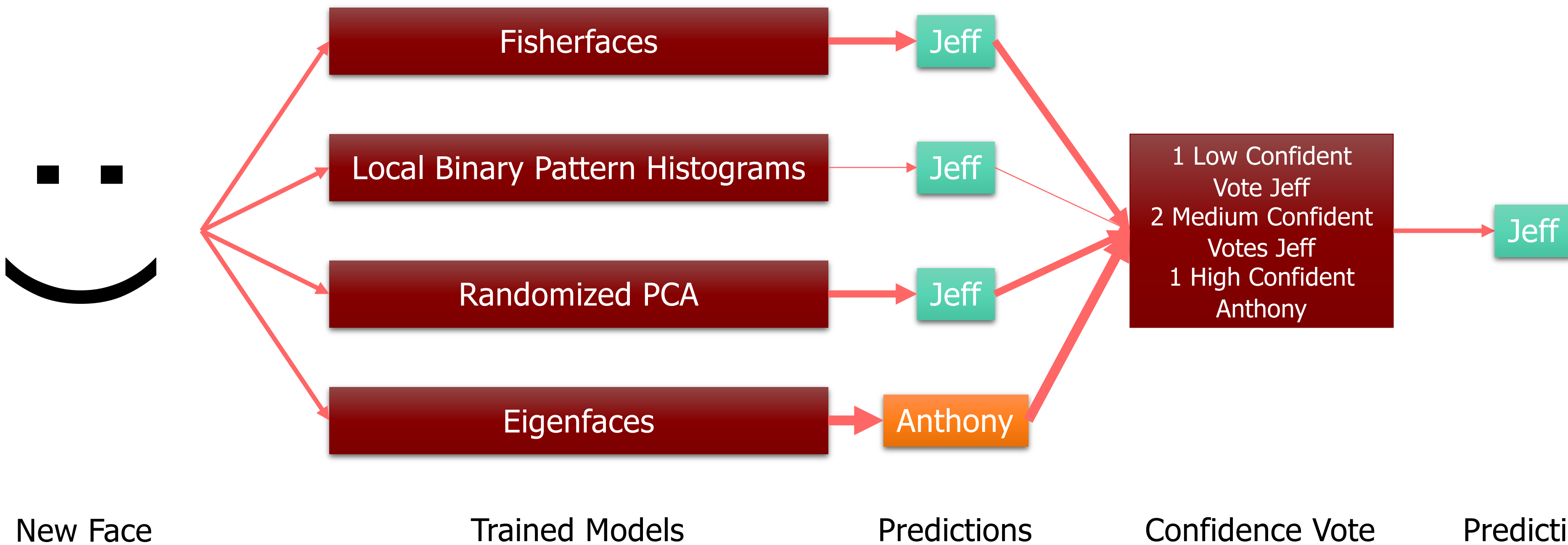
Our ensemble method take into account the confidence of each model



# Proposed Ensemble Method

Our ensemble method take into account the confidence of each model

How do we determine confidence?



# Ensemble Confidence

## A novel way to combine component algorithm distance measures

- $Z_f$ - distance between testing face $\boldsymbol{X}_f$ and nearest neighbor among $k$ training faces $\boldsymbol{Y}$.

$$Z_f = \min_{i=1,2,\ldots,k} \|\mathbf{X}_f - \mathbf{Y}_i\|_2^2$$

- Confidence: probability that a random distance is greater than the observed distance. For multiple algorithms, combine distances by summation.

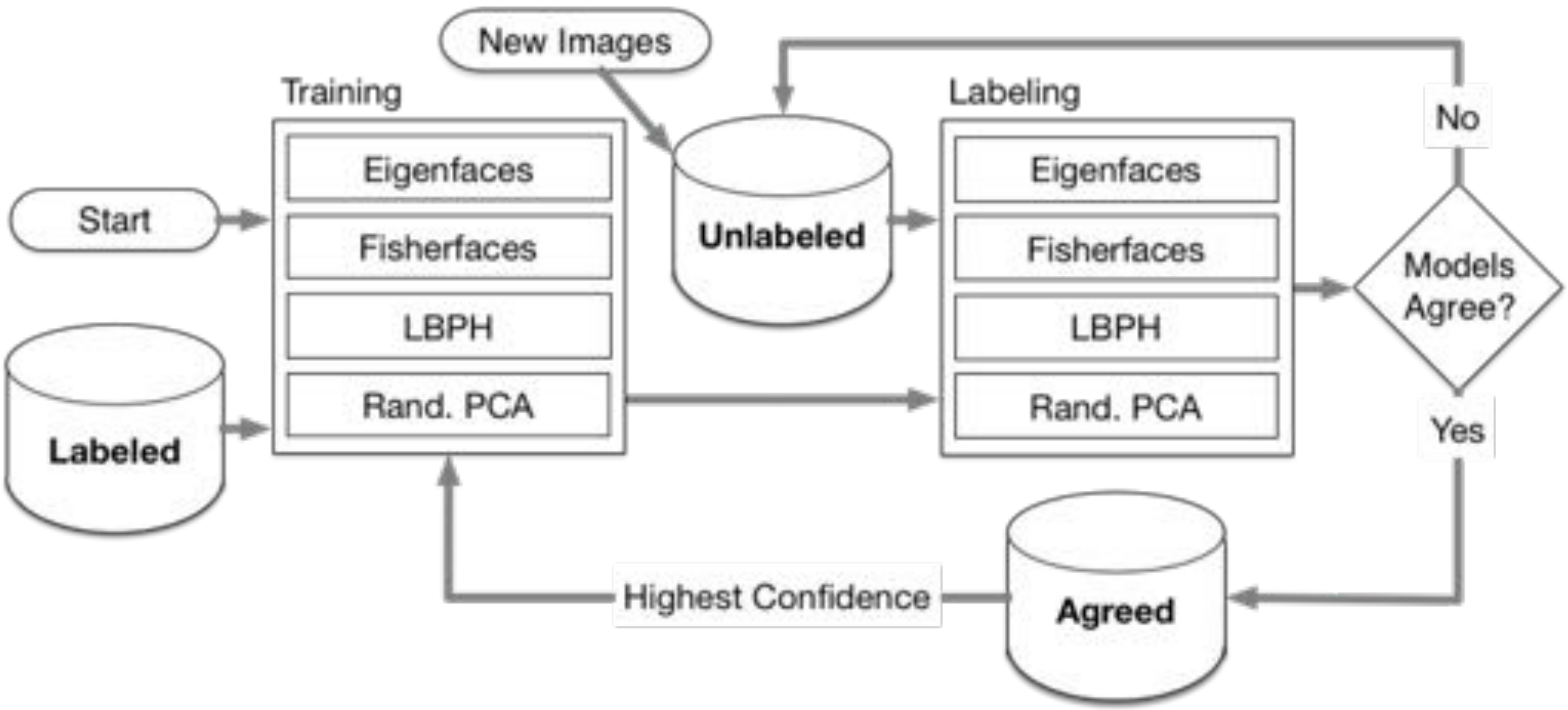
$$C(z) = \Pr(Z \geq z) = \int_z^{\infty} f_Z(t)\ \mathrm{d}t$$

- PDF $f_Z(z)$ is estimated using kernel density estimation, integral transformed and evaluated with Gaussian quadratures.

$$C(z) = \int_0^1 f_Z\left(z + \frac{t}{1-t}\right) \frac{\mathrm{d}t}{(1-t)^2}$$

# Ensemble Method

Idea: Treat high confidence agreements in component algorithms as truth and retrain components.



# Datasets

We used popular small-to-medium sized datasets in face recognition.

**AT&T Faces**

- 40 subjects
- 10 faces per subject
- 112×92 pixel images
- Grayscale

F. S. Samaria and A. C. Harter, "Parameterisation of a stochastic model for human face identification," in *Proceedings of the Second IEEE Workshop on Applications of Computer Vision*. IEEE, 1994, pp. 138–142.

**Extended Yale Database B**

- 38 subjects
- Varied faces per subject (2424 total images)
- 192x160 pixel images
- Grayscale

A. S. Georghiades, P. N. Belhumeur, and D. J. Kriegman, "From few to many: Illumination cone models for face recognition under variable lighting and pose," *IEEE transactions on pattern analysis and machine intelligence*, vol. 23, no. 6, pp. 643–660, 2001.

# Tuning the Ensemble

- Each ensemble method has a few parameters that a user must specify
- These parameters have a large impact on accuracy
- We used an evolutionary algorithm to tune these parameters
- These parameters were evolved in the ensemble method loop

Fisherfaces

Local Binary Pattern Histograms

Randomized PCA

Eigenfaces

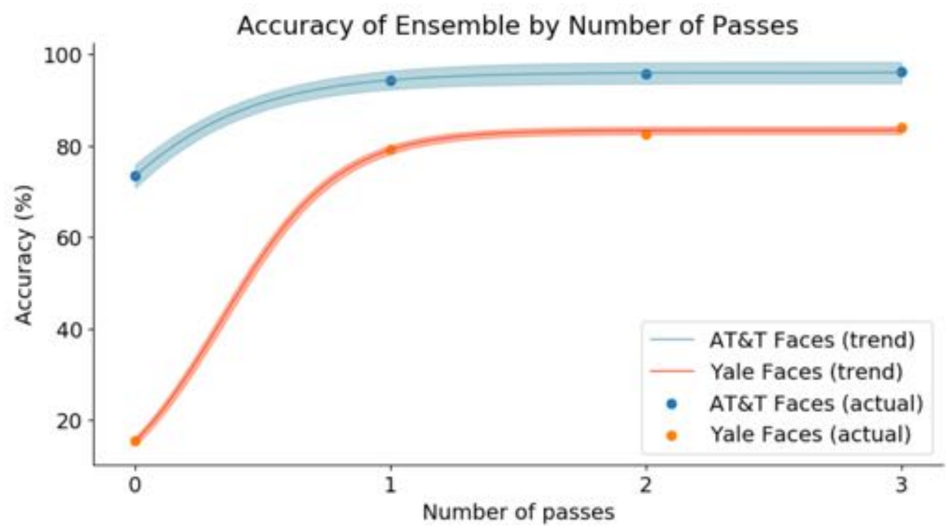
# Accuracy of the Ensemble

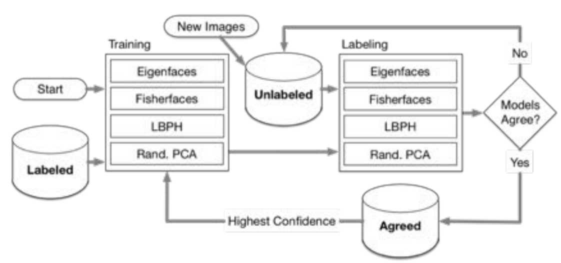
| | AT&T Faces | | Yale Faces | |
|---|---|---|---|---|
| Method | Best | Average | Best | Average |
| **Eigenfaces** | 74.17% | 69.72% | 13.03% | 12.05% |
| **Fisherfaces** | 73.33% | 69.33% | 11.78% | 11.01% |
| **LBPH** | 83.61% | 81.95% | 29.63% | 27.31% |
| **Rand. PCA** | 74.17% | 69.95% | 13.12% | 11.98% |
| **MV Ensemble** | 74.44% | 70.33% | 13.16% | 12.05% |
| **Best Guess** | 86.39% | 84.67% | 29.97% | 27.73% |
| **Ensemble P0** | 76.94% | 73.33% | 16.60% | 15.40% |
| **Ensemble P1** | 96.39% | 94.33% | 80.47% | 79.10% |
| **Ensemble P2** | 98.33% | 95.73% | 83.32% | 82.57% |
| **Ensemble P3** | 98.61% | 95.73% | 85.16% | 84.06% |

# Ensemble as a Face Recognition Algorithm

Evaluating the merit of the proposed ensemble in face recognition

- Each pass adds additional training samples
- These new samples are assumed to be correct, but they are never checked
- Accuracy is over 5 replicate experiments
- Points are fitted with logistic curve
- Shading is standard deviation fitted with logistic curve

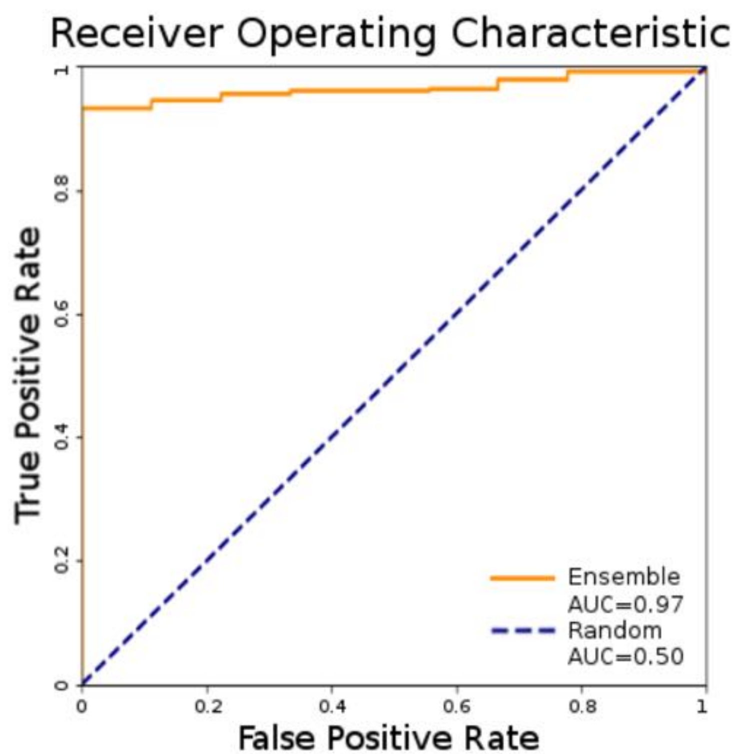


# Ensemble Confidence - Validation

Evaluating the merit of the proposed confidence measure

- ROC curve - false positive rate vs true positive rate varying confidence threshold
- Data points considered are agreements in ensemble.
- Can achieve over 90% true positive rate at 0% false positive (Dataset: AT&T Faces)
- Number of added faces to training is sufficient for deep learning approaches to take over.



# Discussion

What do these results show?

- We have created two things:
  1. A metric for assessing the confidence of a face recognition algorithm
  2. An ensemble method that uses the confidence metric for predicting labels of new faces

- Our proposed ensemble method can be used to improve the performance of face recognition for application with the following properties:
  1. Only a few training examples are available
  2. New samples will be collecting during the *testing* process

- New methods can be added the ensemble as long as they provide some form of distance

- After enough new labeled (or predicted) samples are collected, a tool can switch over to a more accurate system like the Inception-ResNet deep neural network face recognizer.

# Thank You


Anthony Clark
anthonyclark@missouristate.edu
cs.missouristate.edu/AnthonyClark.aspx

Jeff Dale
jdale@ieee.org
linkedin.com/in/jeff-dale-31aa5496/


GitHub
https://github.com/jeff-dale/face-rec-ensemble