

# CONSTRAINED SEMI-SUPERVISED LEARNING USING ATTRIBUTES AND COMPARATIVE ATTRIBUTES

Abhinav Shrivastava, Saurabh Singh, Abhinav Gupta

The Robotics Institute

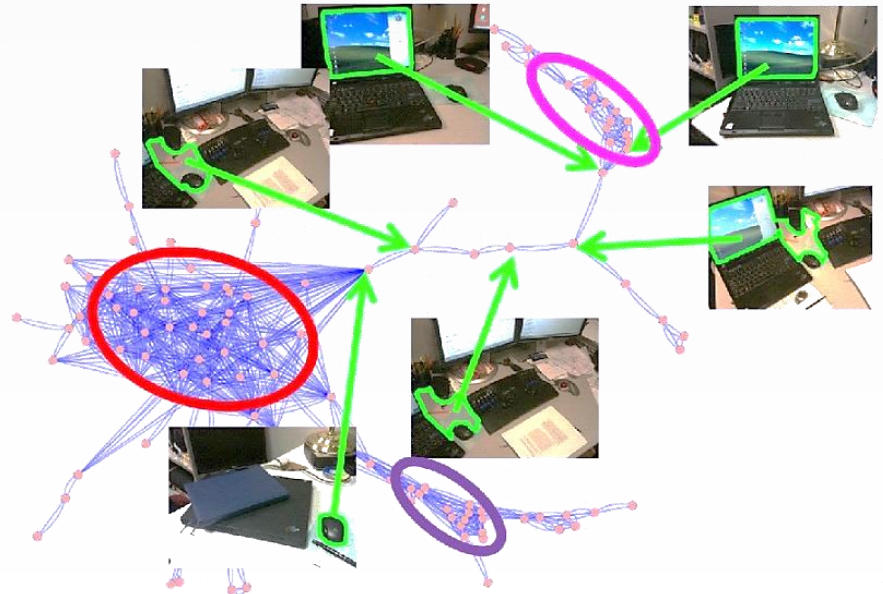
Carnegie Mellon University



## BIG-DATA

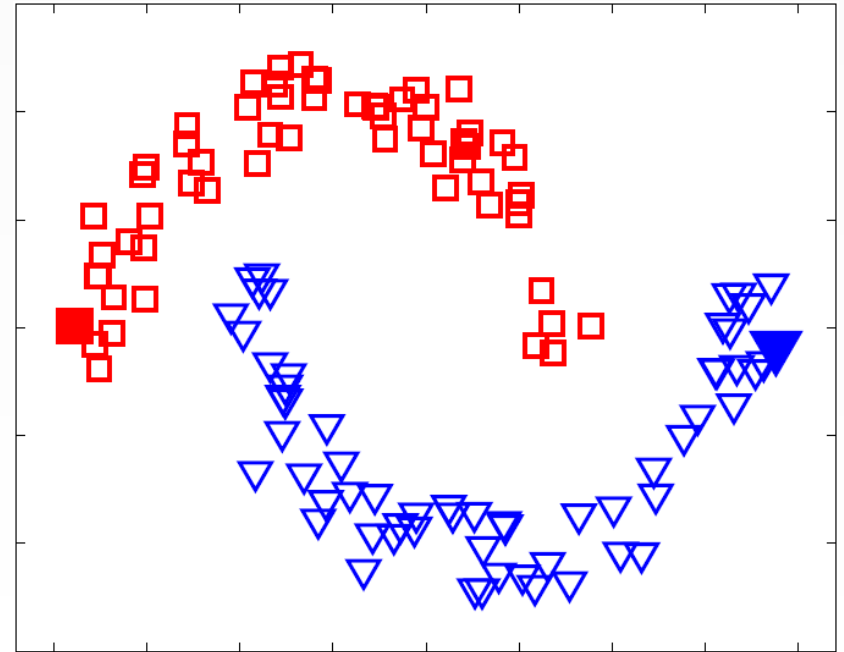
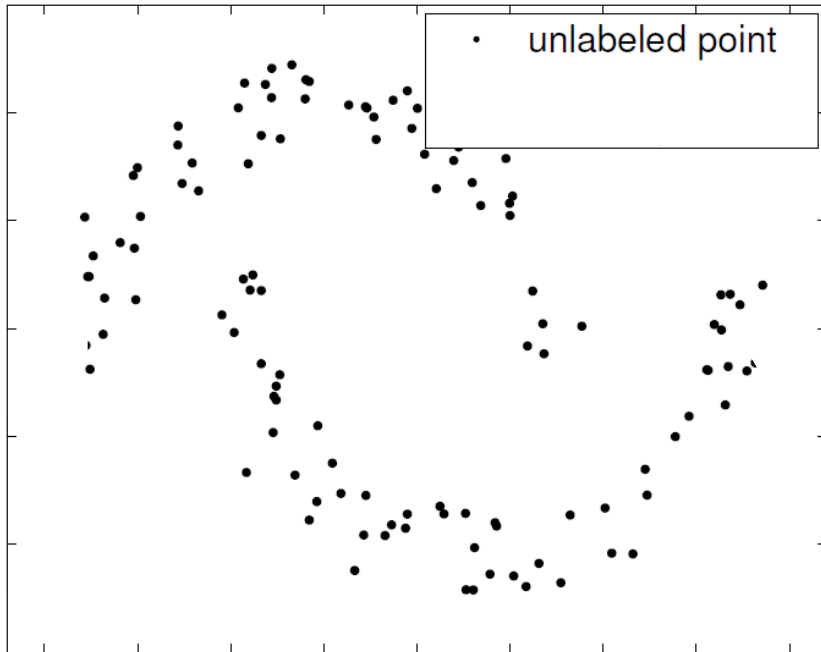


UNSUPERVISED

ACTIVE  
LEARNING SUPERVISED

UNSUPERVISED

SEMI-SUPERVISED

ACTIVE  
LEARNING SUPERVISED

# BOOTSTRAPPING

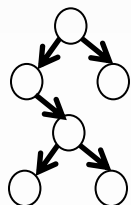
Labeled Seed  
Examples

Train  
Models

Unlabeled  
Data

Select  
Candidates

Amphitheatre



IMAGENET PASCAL2 SUN Database  
facebook Google Image Search bing

Amphitheatre



Add to  
Labeled Set



UNSUPERVISED

SEMI-SUPERVISED

ACTIVE  
LEARNING SUPERVISED

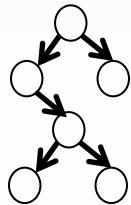
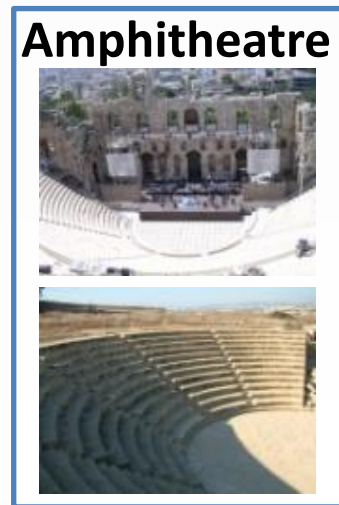
# BOOTSTRAPPING

Labeled Seed  
Examples

Retrain  
Models

Unlabeled  
Data

Select  
Candidates



Add to  
Labeled Set





UNSUPERVISED

SEMI-SUPERVISED

ACTIVE  
LEARNING SUPERVISED

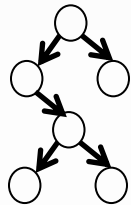
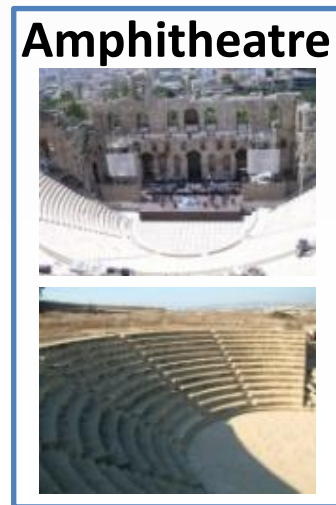
# BOOTSTRAPPING

Labeled Seed  
Examples

Retrain  
Models

Unlabeled  
Data

Select  
Candidates



Add to  
Labeled Set

25<sup>th</sup> Iteration



UNSUPERVISED

SEMI-SUPERVISED

ACTIVE  
LEARNING SUPERVISED

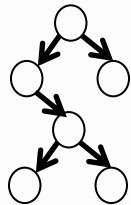
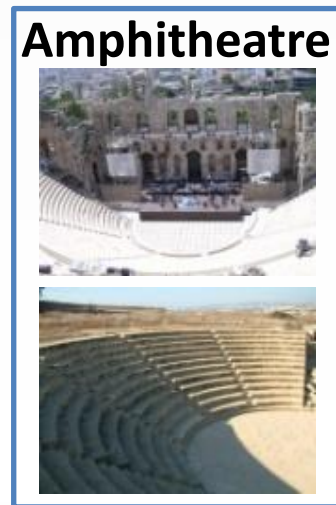
# BOOTSTRAPPING

Labeled Seed  
Examples

Retrain  
Models

Unlabeled  
Data

Select  
Candidates



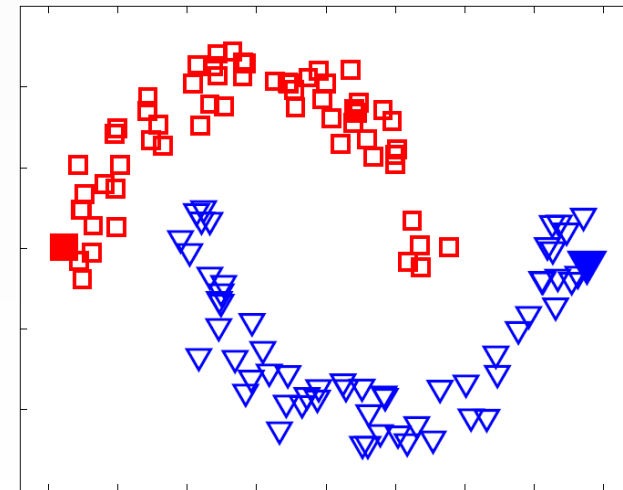
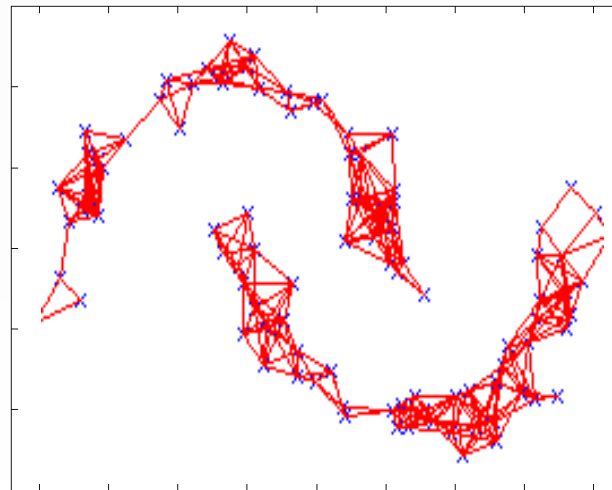
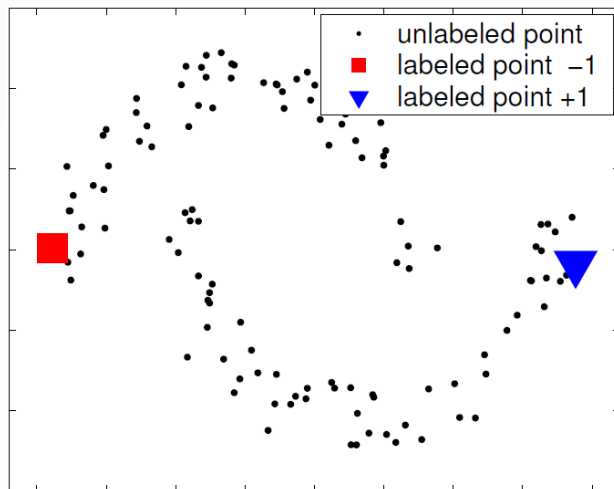
Add to  
Labeled Set



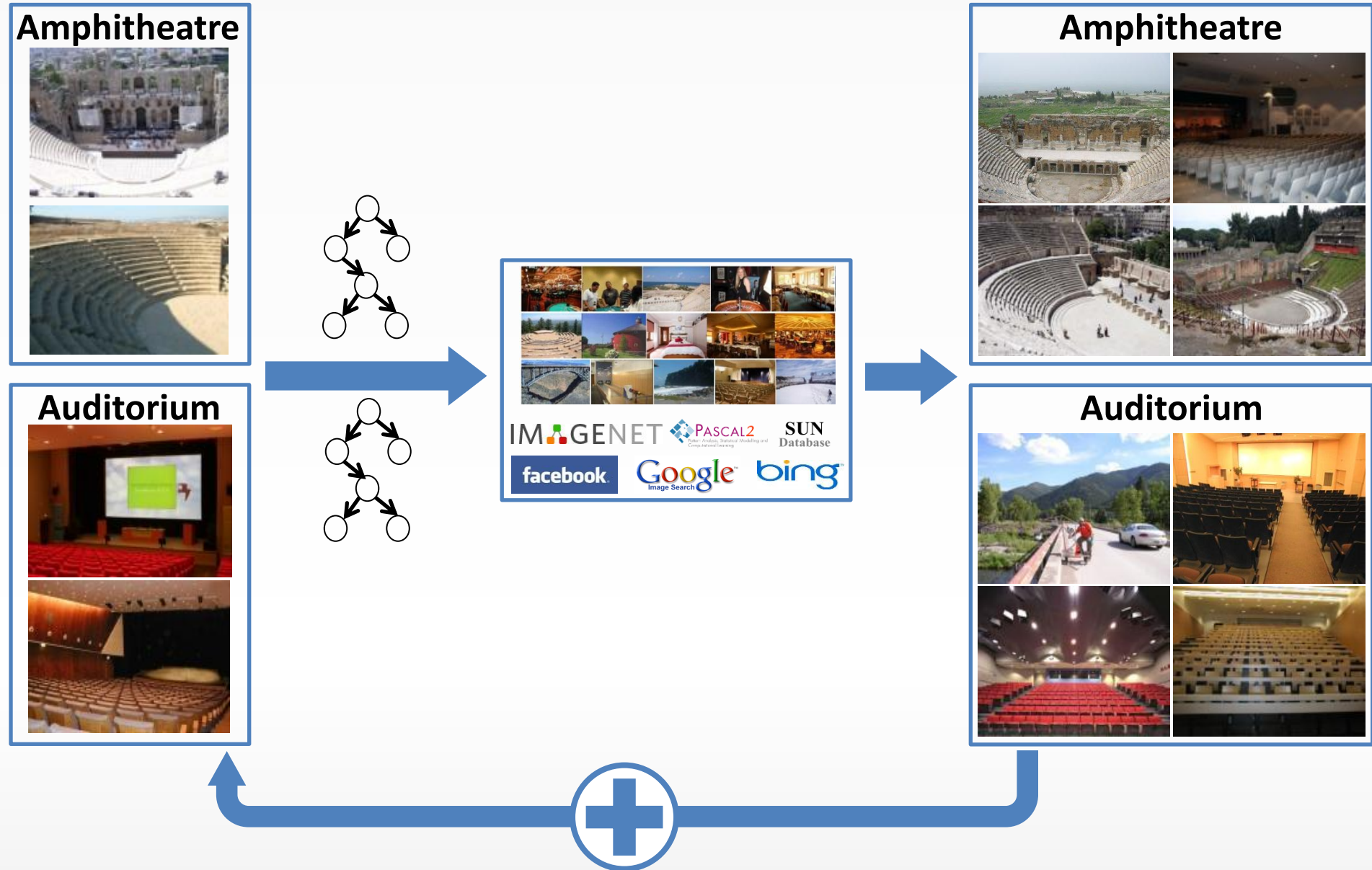
**Semantic Drift**



# GRAPH-BASED METHODS



# OUR APPROACH



# OUR APPROACH

## Joint Learning



## Share Data

Amphitheatre



Amphitheatre



Auditorium



Auditorium



# BINARY ATTRIBUTES (BA)



Conference Room

Indoor

Tables and Chairs

Man-made



Banquet Hall



# BINARY ATTRIBUTES (BA)

Amphitheatre



Man-made

Large Seating Capacity

Auditorium





# BINARY ATTRIBUTES (BA)

Tables and Chairs



Large Seating Capacity



Indoor



Man-made



# Auditorium

Indoor

Has Seat Rows



# Auditorium

Indoor

Has Seat Rows





# Auditorium

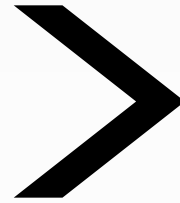
Indoor

Has Seat Rows



# SHARING VIA DISSIMILARITY

## Amphitheatre



## Auditorium



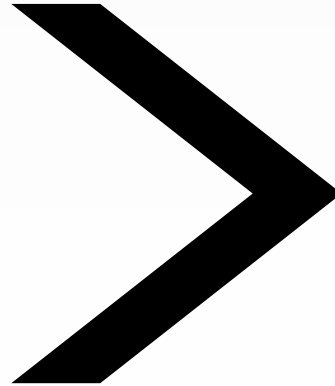
**Has Larger  
Circular Structures**



# Amphitheatre

Has Larger  
Circular  
Structures

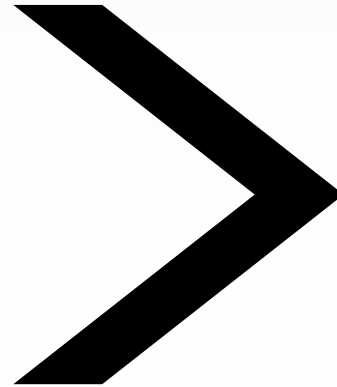
# Auditorium



# Amphitheatre

Has Larger  
Circular  
Structures

# Auditorium



# Amphitheatre

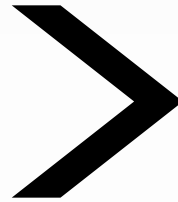
Has Larger  
Circular  
Structures

# Auditorium



# DISSIMILARITY

## COMPARATIVE ATTRIBUTES



**Has Larger  
Circular Structures**



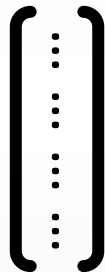
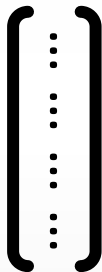


# DISSIMILARITY

## COMPARATIVE ATTRIBUTES



Has Larger  
Circular  
Structures



### Features

- GIST
- RGB (Tiny Image)
- Line Histogram of:
  - Length
  - Orientation
- LAB histogram

[Hays and Efros, SIGGRAPH 2007]

[Oliva and Torralba, 2006]

[Torralba et al., PAMI, 2008]

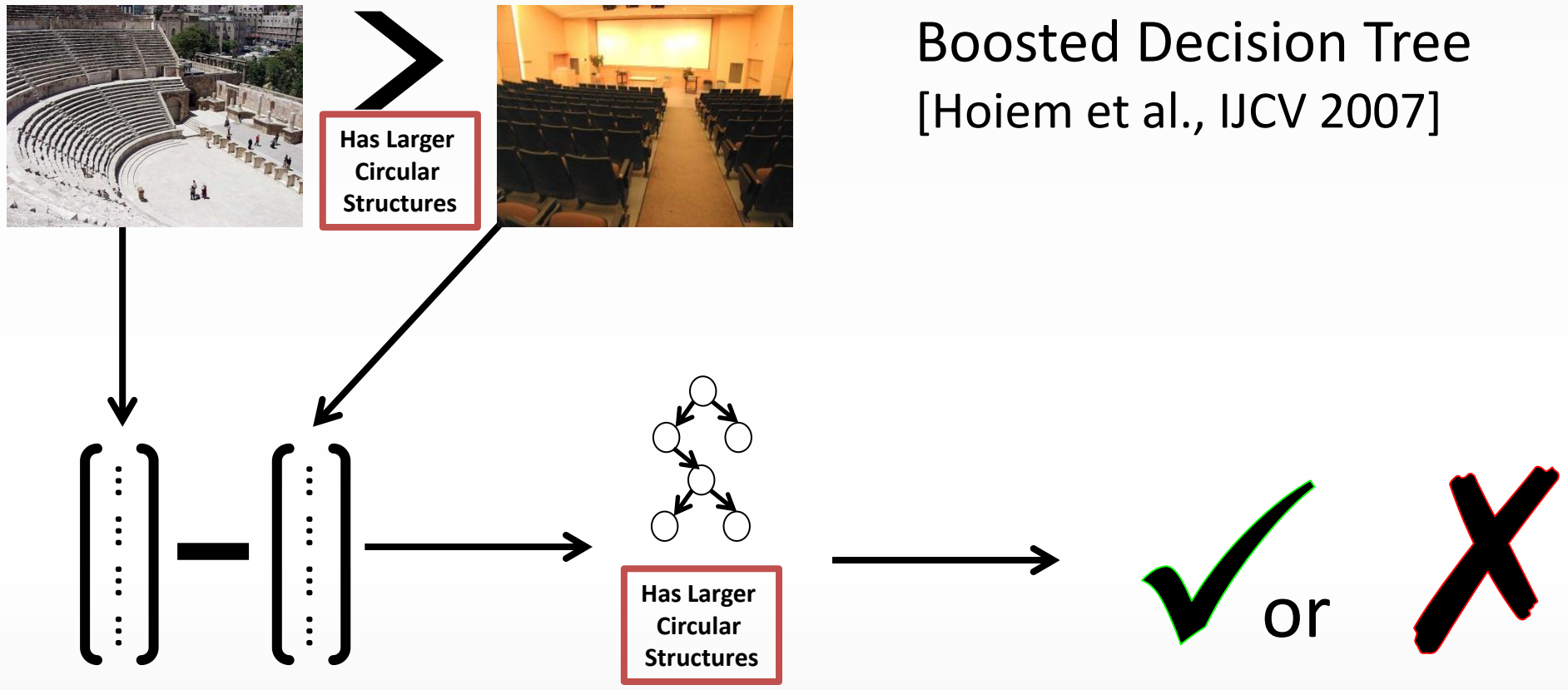


# DISSIMILARITY

## COMPARATIVE ATTRIBUTES

### Classifier

Boosted Decision Tree  
[Hoiem et al., IJCV 2007]



# COMPARATIVE ATTRIBUTES

## Is More Open

Amphitheatre > Barn

Amphitheatre > Conference Room

Desert > Barn

## Has Taller Structures

Church (Outdoor) > Cemetery

Barn > Cemetery

# Selected Candidates

## Labeled Seed Examples

### Amphitheatre



### Auditorium

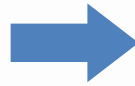


## Bootstrapping

### Amphitheatre



### Auditorium



# Selected Candidates

## Labeled Seed Examples

### Amphitheatre



### Auditorium



## Bootstrapping

### Amphitheatre



### Auditorium



## Our Approach (Constrained Bootstrapping)

### Amphitheatre



### Auditorium



### Attributes

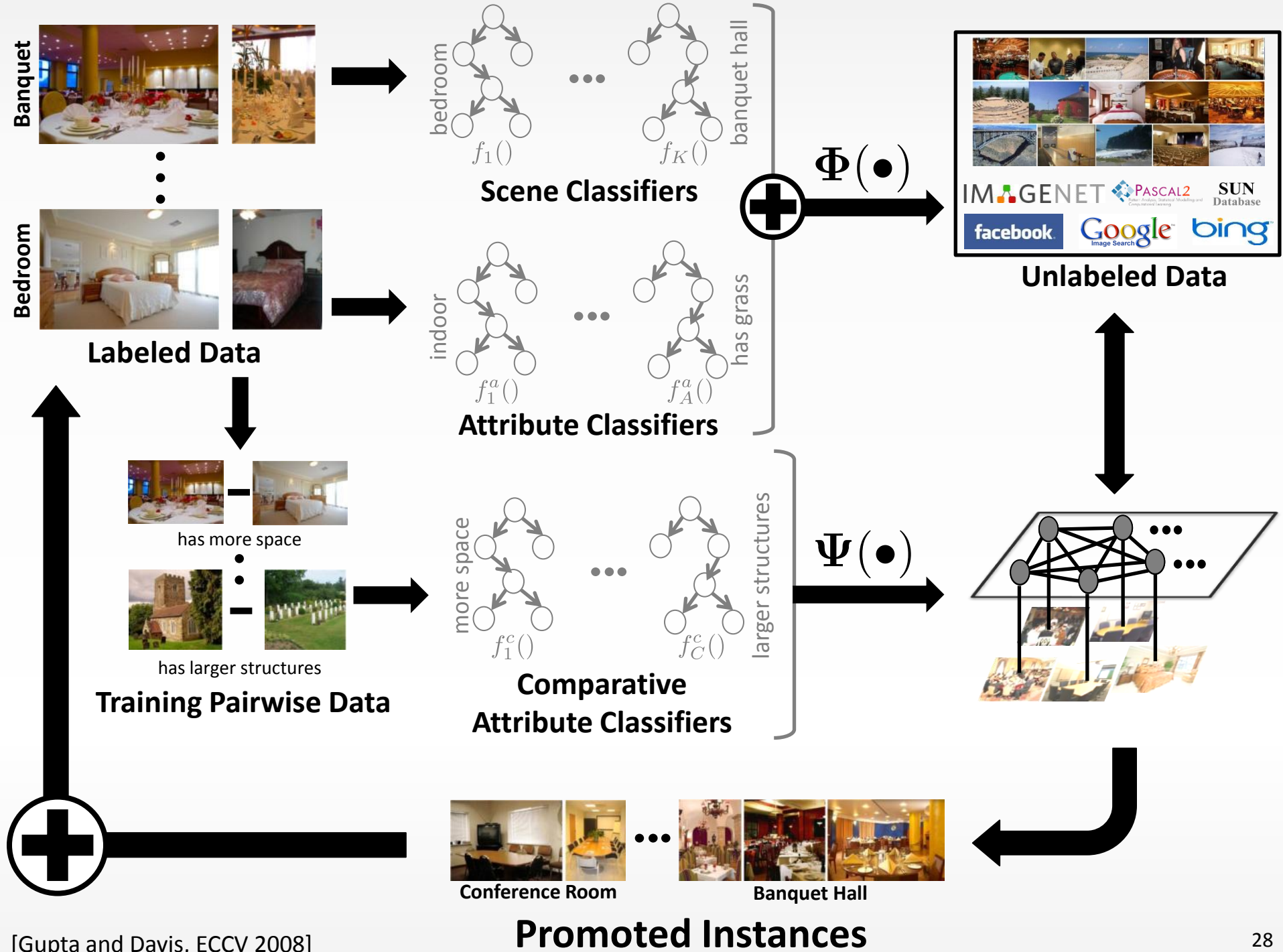
Indoor

Has Seat Rows

### Comparative Attributes

Has Larger Circular Structures







Seed  
Examples



# Conference Room

Iteration 1



Iteration 40



# Introspection

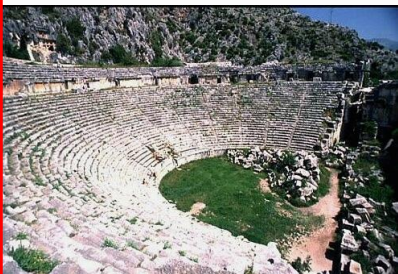


Seed Images

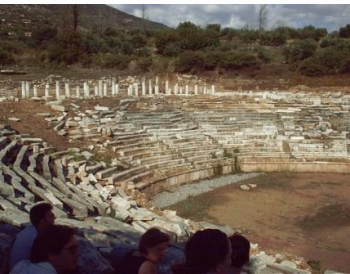


# Amphitheatre

Bootstrapping



BA Constraints



Our Approach





Seed Images



# Bridge

Bootstrapping



BA Constraints



Our Approach



# **EXPERIMENTAL EVALUATION**

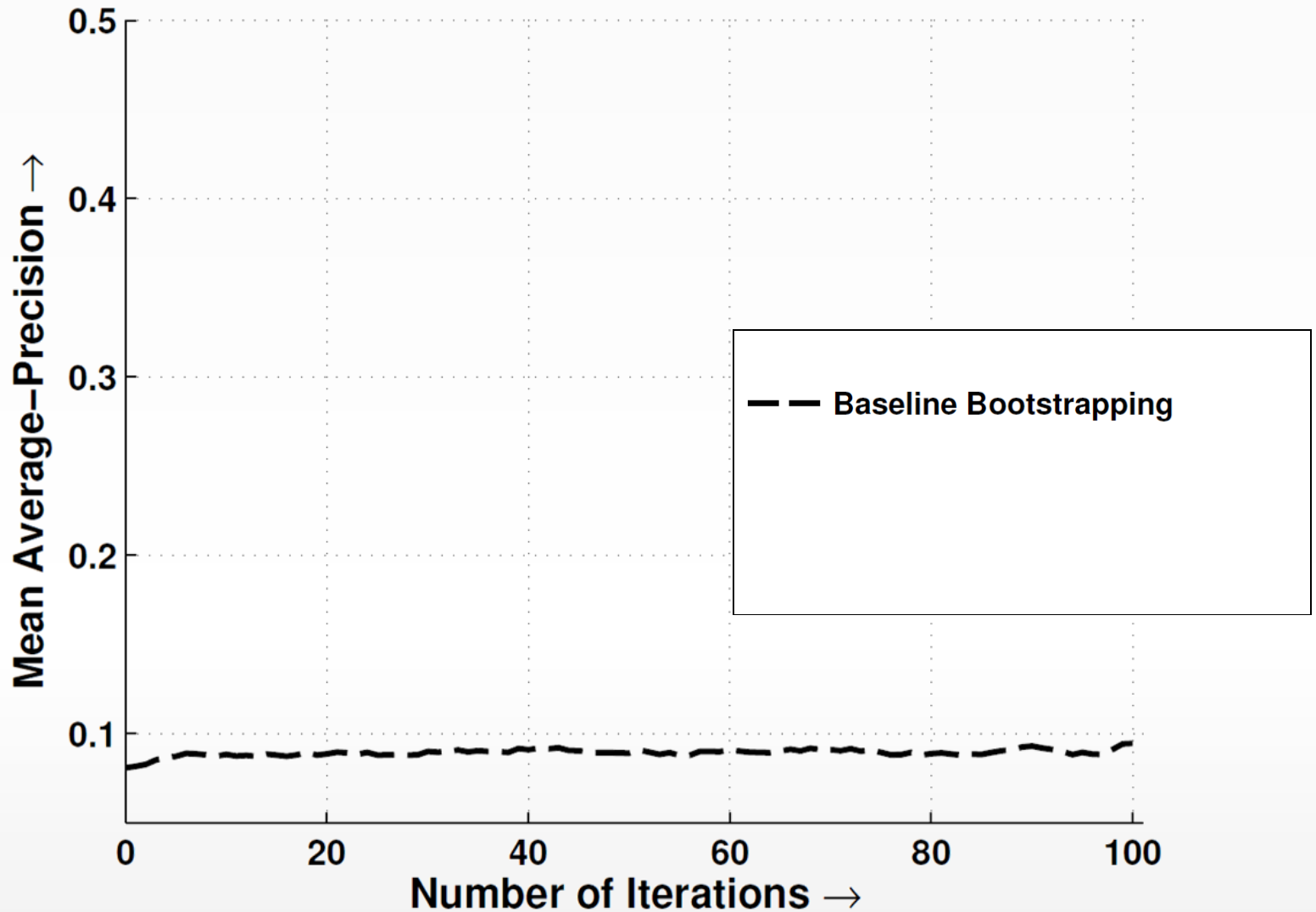
# CONTROL EXPERIMENTS

# Images  
(SUN Database)

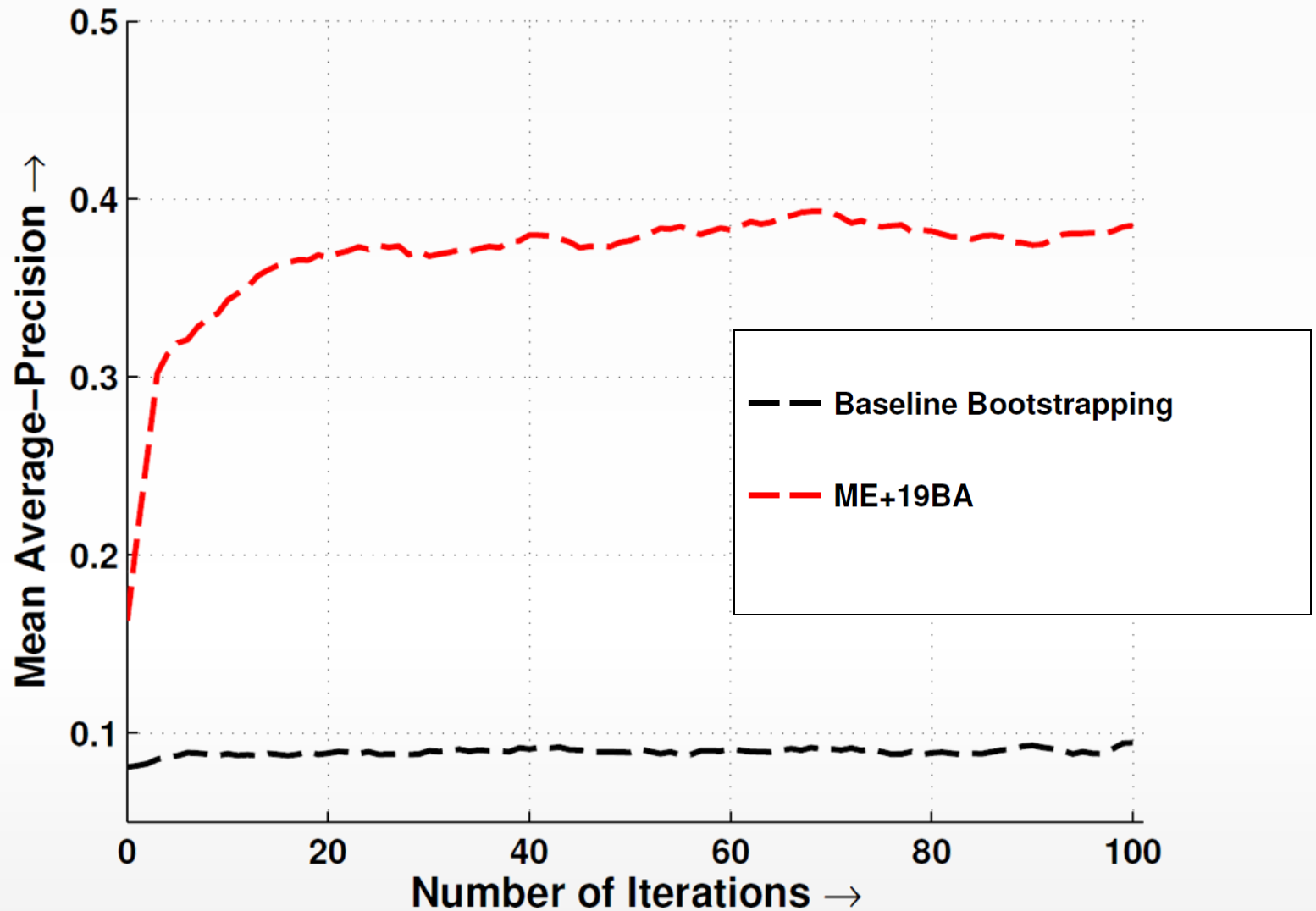
15 Scene Classes	2 (seed)
<b>Black-box</b> Binary Attributes (BA)	25 (separate)
<b>Black-box</b> Comparative Attributes (CA)	25 (separate)
Unlabeled Dataset (Distractors)	18,000 (9,500)
Test Set	50



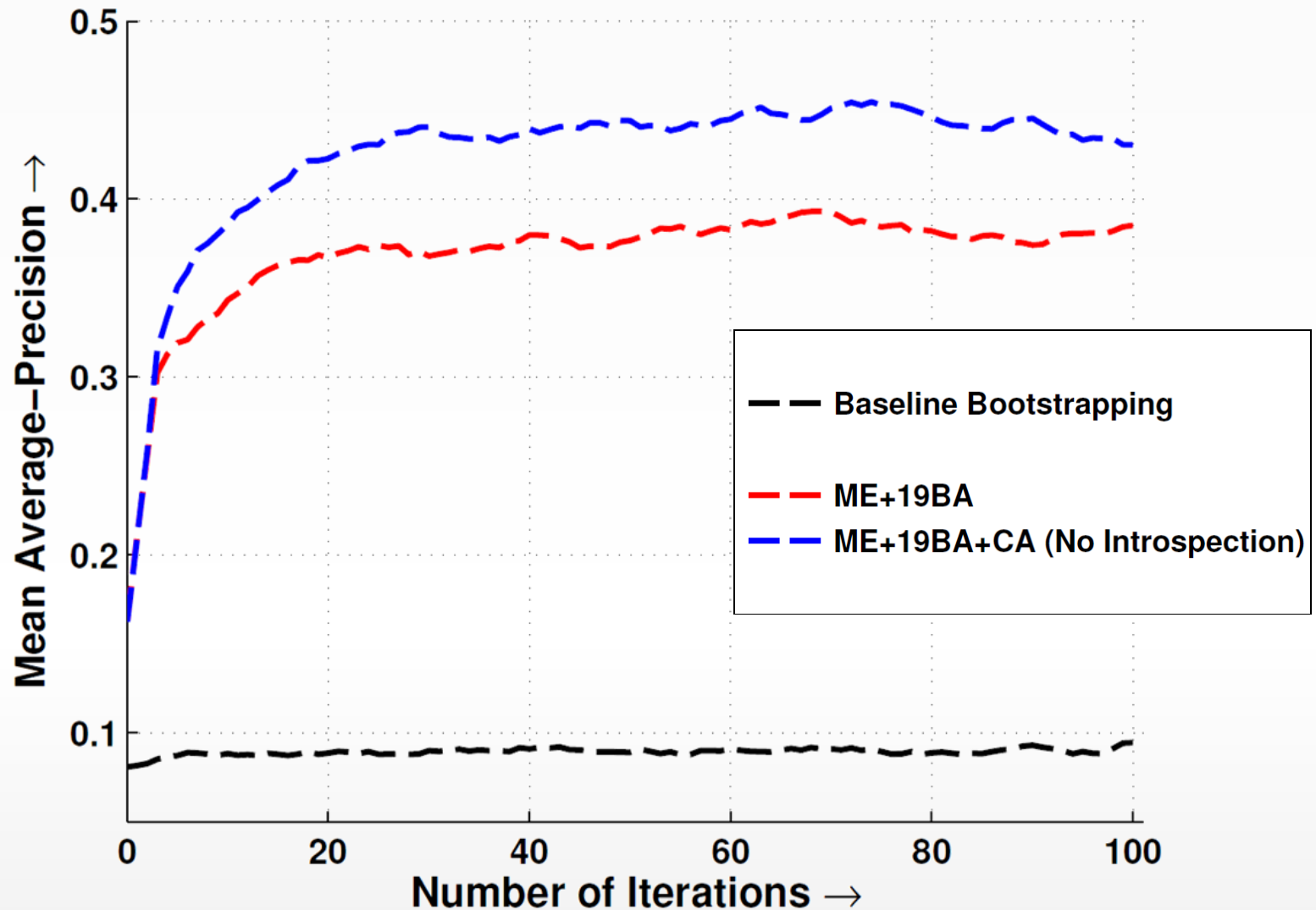
# CONTROL EXPERIMENTS



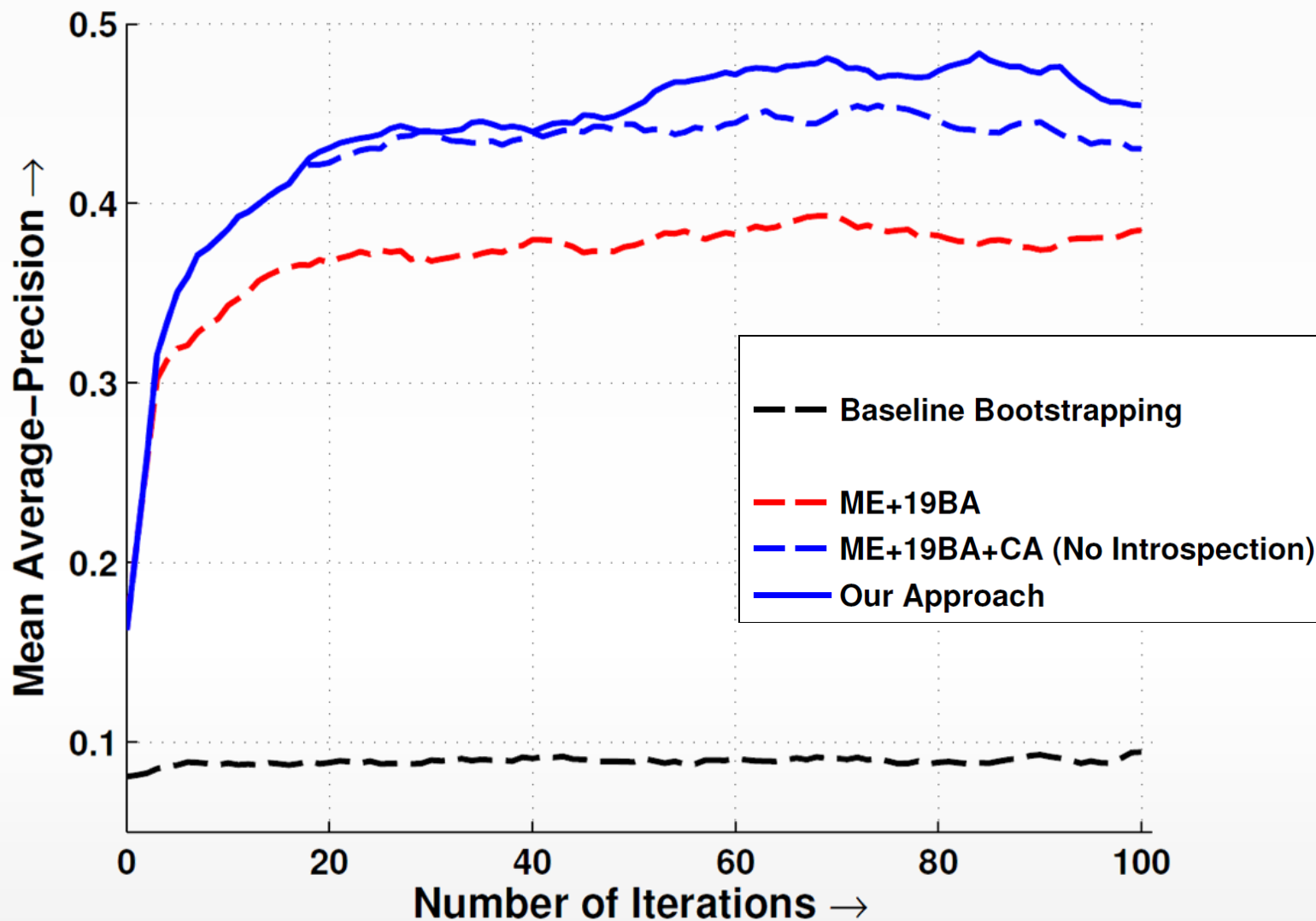
# CONTROL EXPERIMENTS



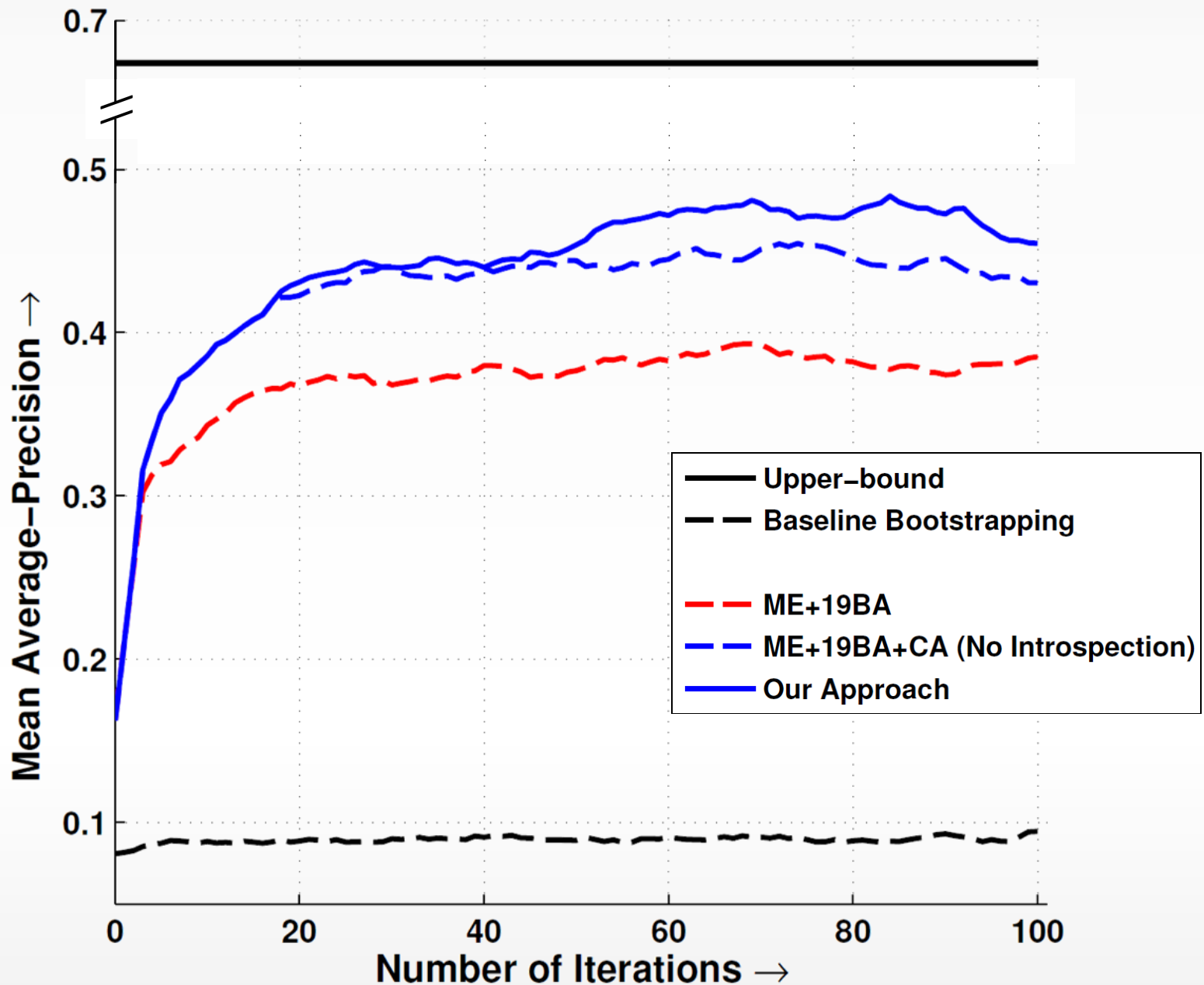
# CONTROL EXPERIMENTS



# CONTROL EXPERIMENTS

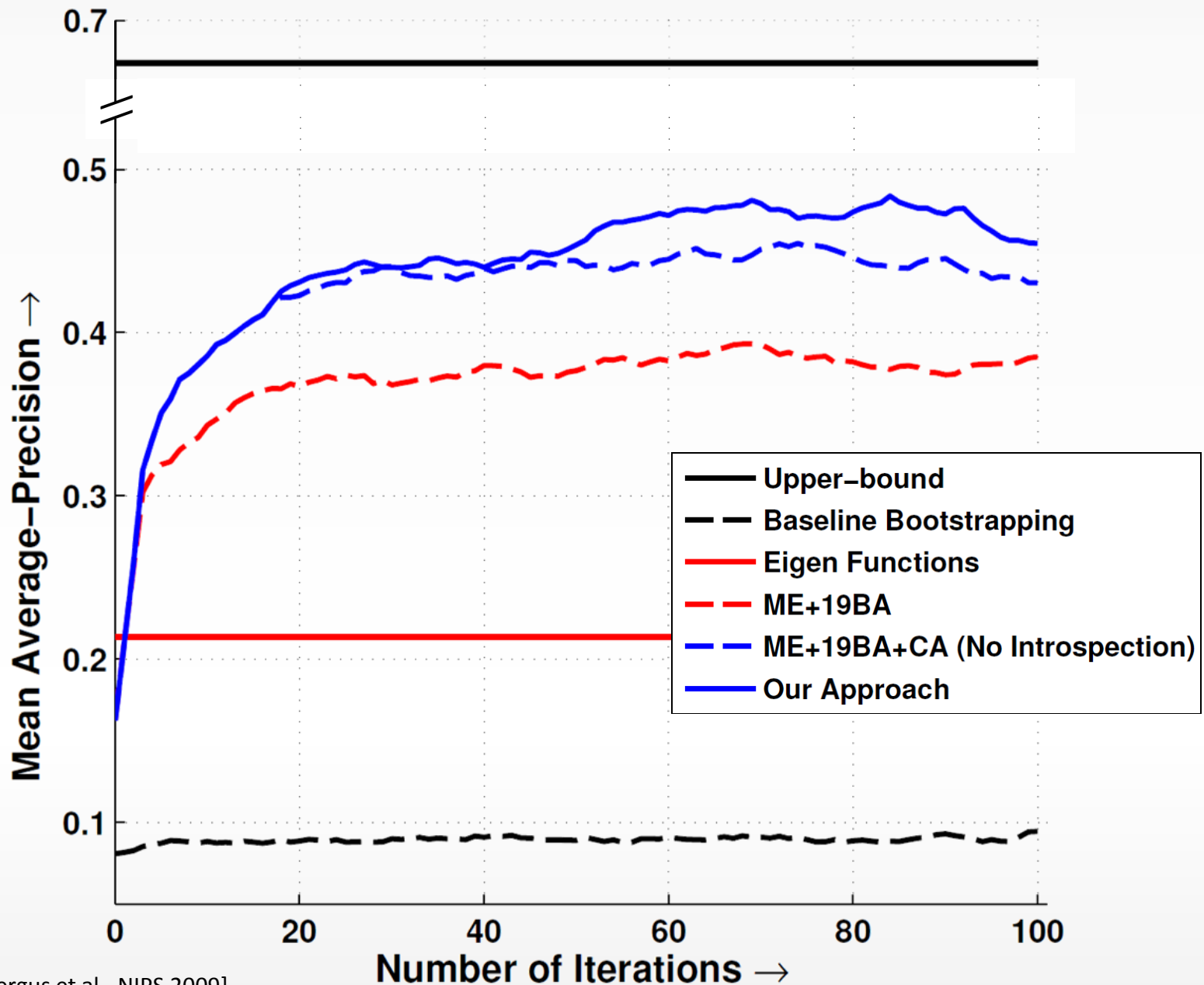


# CONTROL EXPERIMENTS





# CONTROL EXPERIMENTS



# Banquet Hall

Seed Images



1



10



40



Iterations  
↓

# CONTROL EXPERIMENTS

# Images  
(SUN Database)

15 Scene Classes	2 (seed)
<b>Black-box</b> Binary Attributes (BA)	25 (separate)
<b>Black-box</b> Comparative Attributes (CA)	25 (separate)
Unlabeled Dataset (Distractors)	18,000 (9,500)
Test Set	50

# CO-TRAINING (SMALL SCALE)

# Images  
(SUN Database)

15 Scene Classes	2 (seed)
<del>Black-box</del> Binary Attributes (BA)	15x2 (seed)
<del>Black-box</del> Comparative Attributes (CA)	15x2 (seed)
Unlabeled Dataset (Distractors)	18,000 (9,500)
Test Set	50



Seed Images



# Bedroom

Bootstrapping

Iteration-1



Iteration-60

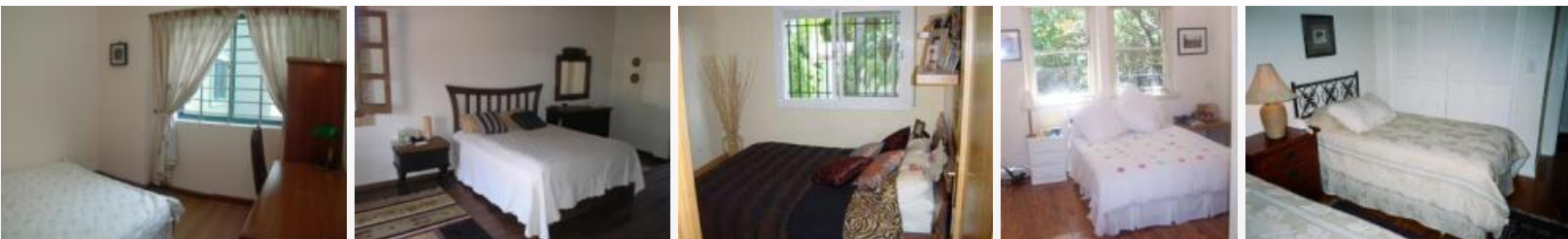


Our Approach

Iteration-1

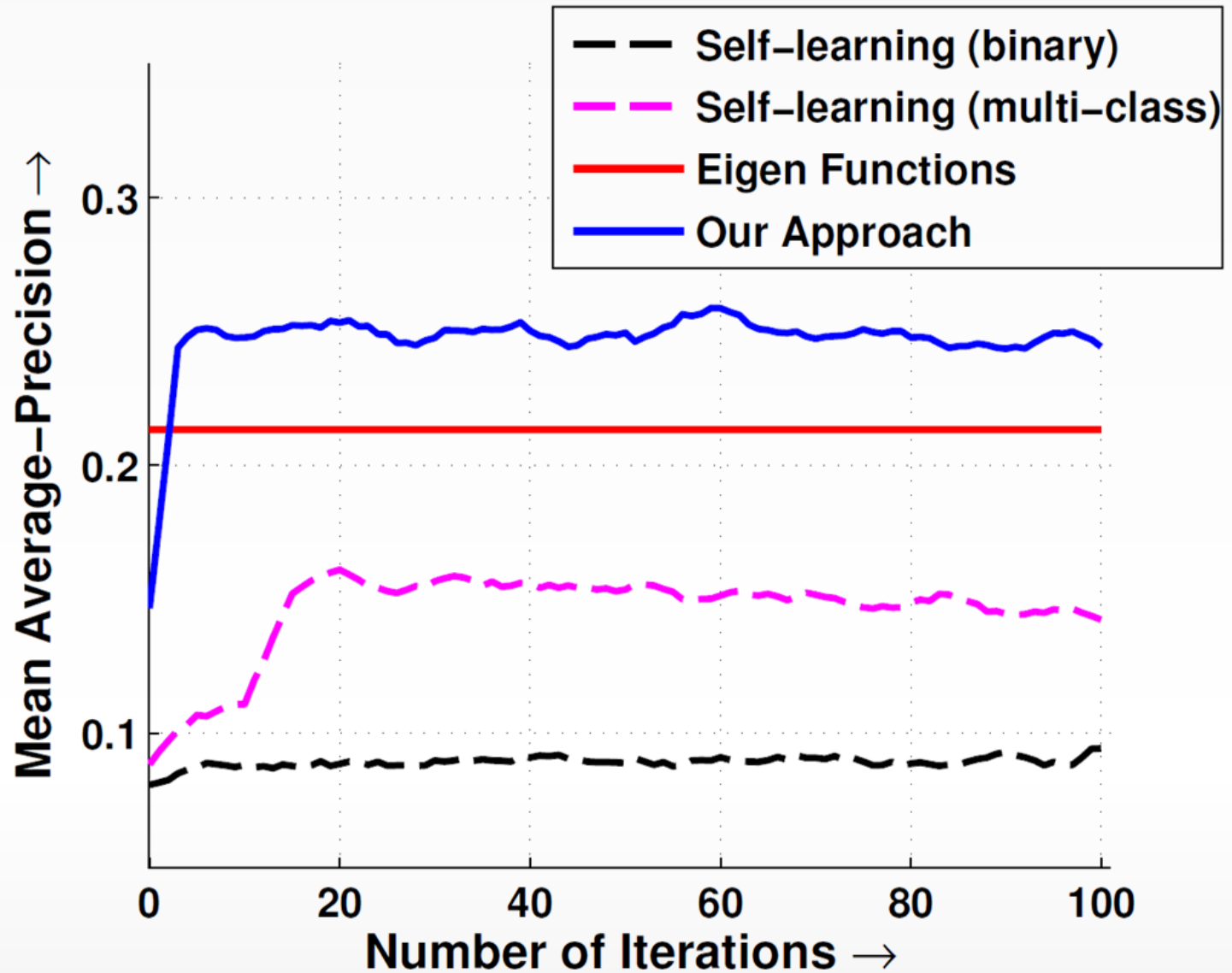


Iteration-60





# SCENE CLASSIFICATION



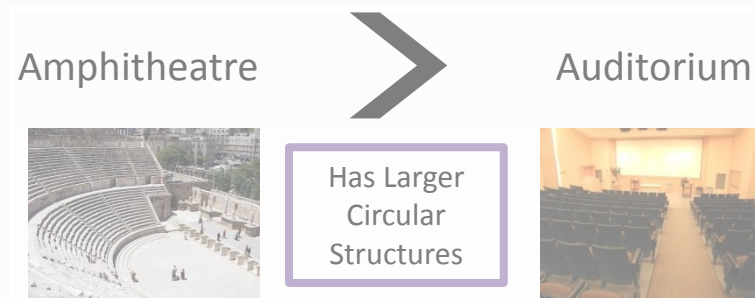
# CO-TRAINING (LARGE SCALE)

- 15 Scene Categories
  - 25 Seed images / category
- Unlabeled Set
  - **1Million** (SUN Database + ImageNet)
  - **>95%** distractors

**Improve 12 out of 15 scene classifiers**

# CONCLUSION

- Sharing via Dissimilarities



- Constrained Bootstrapping

