

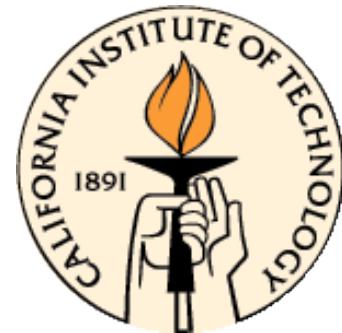
Visual Recognition with Humans in the Loop

Serge Belongie
UC San Diego



Steve Branson
Catherine Wah
Boris Babenko
Florian Schroff

Peter Welinder
Pietro Perona



Outline

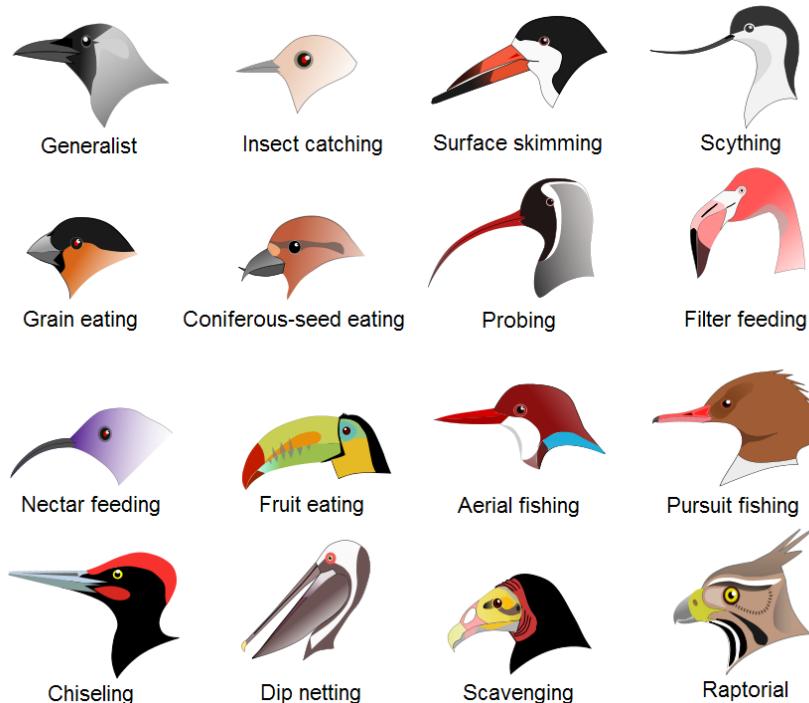
- Visipedia project overview
- Relevant Work
- Birds-200 dataset
- “Visual 20 Questions” game
- Results
- Discussion

Outline

- Visipedia project overview
- Relevant Work
- Birds-200 dataset
- “Visual 20 Questions” game
- Results
- Discussion

What Is Visipedia?

- The visual counterpart to Wikipedia
- A user-generated encyclopedia of visual knowledge
- An effort to associate articles with large quantities of well-organized, intuitive visual concepts



<http://en.wikipedia.org/wiki/Bird>

Motivation

- People will willingly label or organize certain images if:
 - They are interested in a particular subject matter
 - They have the appropriate expertise



Ring-tailed lemur



Thruxton Jackaroo

Motivation

- Construct a more comprehensive and intuitive knowledge base of visual objects
- Provide services like better text-to-image search and image-to-article search



Your continued donations keep Wikipedia running!

[Log in / create account](#)

[article](#) [discussion](#) [edit this page](#) [history](#)

Blue Jay

From Wikipedia, the free encyclopedia
(Redirected from [Cyanocitta cristata](#))

For other uses, see [Blue Jay \(disambiguation\)](#).

The Blue Jay (*Cyanocitta cristata*) is a passerine bird, and a member of the family Corvidae native to North America. It belongs to the "blue" or American jays, which are, among the Corvidae, not closely related to other jays. It is adaptable, aggressive and omnivorous, and has been colonizing new habitat for many decades.

[Contents \[hide\]](#)

[1 Description](#)
[1.1 Vocalizations](#)
[2 Distribution and habitat](#)

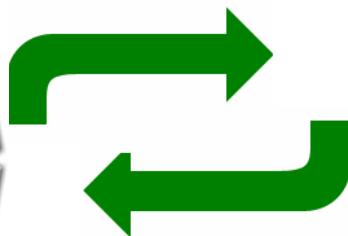
Blue Jay

A photograph of a blue jay perched on a snow-covered branch. The bird has its characteristic blue and black plumage. The background is a soft-focus snowy landscape.

In Algonquin Provincial Park (Canada), the large subspecies *Cyanocitta cristata bromia* occurs.

Populating Visipedia

- Populate Wikipedia articles with more visual data using large quantities of unlabeled data on the web



World wide web



Visipedia

Outline

- Visipedia project overview
- **Relevant Work**
- Birds-200 dataset
- “Visual 20 Questions” game
- Results
- Discussion

Related Work: Systems

- Botanist's Field Guide [Belhumeur et al. '08]
- Oxford Flowers [Nilsback & Zisserman '08]
- STONEFLY9 [Martínez-Muñoz et al. '09]
- omoby [IQEngines.com '10]
- 20 Questions game [20q.net]
- ReCAPTCHA [von Ahn et al. '08]
- Wikimedia Commons



Related Work: Methods

- Relevance Feedback
- Active Learning
- Expert Systems
- Decision Trees
- Feature Sharing & Taxonomies
- Parts & Attributes
- Crowdsourcing & Human Computation

Attribute-Based Classification

- Train classifiers on attributes instead of objects
- Attributes are shared by different object classes
- Attributes provide the ingredients necessary to recognize each object class

otter

black: yes
white: no
brown: yes
stripes: no
water: yes
eats fish: yes



polar bear

black: no
white: yes
brown: no
stripes: no
water: yes
eats fish: yes



zebra

black: yes
white: yes
brown: no
stripes: yes
water: no
eats fish: no



Lampert et al. 2009

Farhadi et al. 2009



WIKIPEDIA
The Free Encyclopedia

article

discussion

view source

history

Try Beta

Log in / create account

Bird

From Wikipedia, the free encyclopedia

"Aves" redirects here. For other uses, see [Aves \(disambiguation\)](#).

For other uses, see [Bird \(disambiguation\)](#).

navigation

- [Main page](#)
- [Contents](#)
- [Featured content](#)
- [Current events](#)
- [Random article](#)

search

interaction

- [About Wikipedia](#)
- [Community portal](#)
- [Recent changes](#)
- [Contact Wikipedia](#)
- [Donate to Wikipedia](#)
- [Help](#)

toolbox

- [What links here](#)
- [Related changes](#)
- [Upload file](#)
- [Special pages](#)
- [Printable version](#)
- [Permanent link](#)
- [Cite this page](#)

languages

- [Acéh](#)
- [Azerbaijani](#)

Birds (class Aves) are winged, bipedal, endothermic (warm-blooded), egg-laying, vertebrate animals. There are around 10,000 living species, making them the most numerous tetrapod vertebrates. They inhabit ecosystems across the globe, from the Arctic to the Antarctic. Extant birds range in size from the 5 cm (2 in) Bee Hummingbird to the 3 m (10 ft) Ostrich. The fossil record indicates that birds evolved from theropod dinosaurs during the Jurassic period, around 150–200 Ma (million years ago), and the earliest known bird is the Late Jurassic *Archaeopteryx*, c 150–145 Ma. Most paleontologists regard birds as the only clade of dinosaurs to have survived the Cretaceous–Tertiary extinction event approximately 65.5 Ma.

Modern birds are characterised by feathers, a beak with no teeth, the laying of hard-shelled eggs, a high metabolic rate, a four-chambered heart, and a lightweight but strong skeleton. All birds have forelimbs modified as wings and most can fly, with some exceptions including ratites, penguins, and a number of diverse endemic island species. Birds also have unique digestive and respiratory systems that are highly adapted for flight. Some birds, especially corvids and parrots, are among the most intelligent animal species; a number of bird species have been observed manufacturing and using tools, and many social species exhibit cultural transmission of knowledge across generations.

Many species undertake long distance annual migrations, and many more perform shorter irregular movements. Birds are social; they communicate using visual signals and through calls and songs, and participate in social behaviours including cooperative breeding and hunting, flocking, and mobbing of predators. The vast majority of bird species are socially monogamous, usually for one breeding season at a time, sometimes for years, but rarely for life. Other species have breeding systems that are polygynous ("many females") or, rarely, polyandrous ("many males"). Eggs are usually laid in a nest and incubated by the

Birds
Fossil range: Late Jurassic–Recent, 150–0 Ma

PreC E O S D C P T J K Pg N



Scarlet Robin, *Petroica boodang*

Scientific classification

Domain:	Eukaryota
Kingdom:	Animalia
Subkingdom:	Eumetazoa
(unranked)	Bilateria

Wikimedia Commons

See also: [Category:Dog breeds](#)

Only a few examples, see [List of dog breeds](#) for more images!

Beagle Border Collie Bull Terrier Dachshund

See also: [Category:Dog behavior](#)

Drinking dogs Dogs eating Yawning dogs Sleeping dogs

See also: [Category:Dog anatomy](#)

Anatomical structures Dog skeletons Dog skulls Dog teeth

- Multiple ways of organizing sub-categories and visual information
- Sub-categories or clusters are represented by some exemplar image

Motivation (Computer Vision Perspective)

- Need for more training data
 - Beyond the capacity of any one research group
 - Better quality control
- Need for more realistic data
 - Let people define what tasks are important
 - Study tightly-related categories

Dealing With a Large Number of Related Classes

- Standard classification methods fail because:
 - Only small number of training examples per class are available
 - Variation between classes is small
 - Variation within a class is often still high



Brewer's Sparrow



Vesper Sparrow



(A) Easy for Humans



Chair? Airplane? ...

(B) Hard for Humans



Finch? Bunting?...

(C) Easy for Humans



Yellow Belly? Blue Belly? ...

Outline

- Visipedia project overview
- Relevant Work
- **Birds-200 dataset**
- “Visual 20 Questions” game
- Results
- Discussion

Birds-200 Dataset



6033 images over 200 bird species

Image Harvesting

- Flickr: text search on species name
- MTurk: presence/absence and bounding boxes

The logo for Flickr, featuring the word "flickr" in a lowercase, sans-serif font. The letters are colored blue, except for the letter "i" which is pink.The logo for Amazon Mechanical Turk. It features the word "amazon" in black, the word "mechanical" in blue, and "turk" in dark blue. Below "mechanical" is the text "Artificial Intelligence" in light blue. To the left of "amazon" is a small "beta" label and the Amazon smile logo.

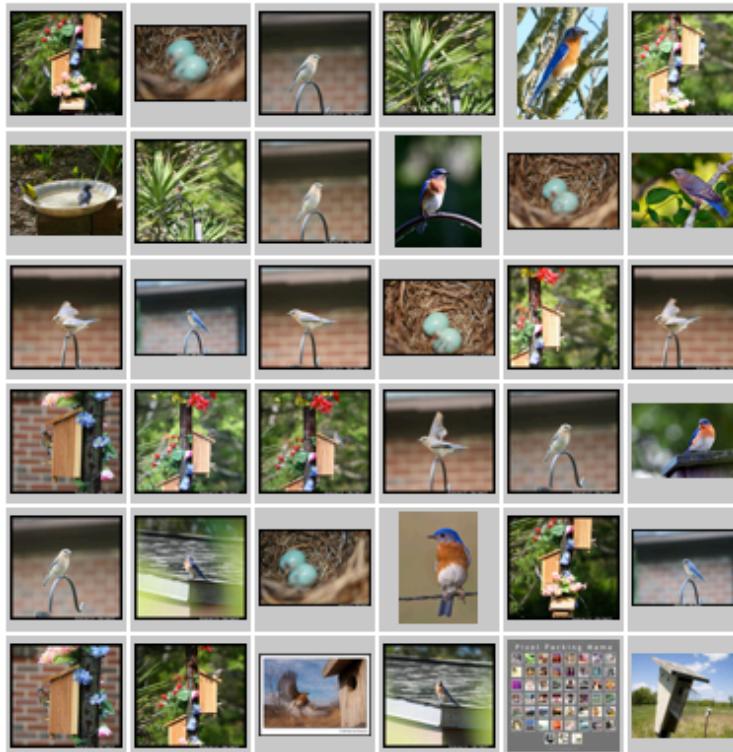
Illustrations of Eastern Bluebird



Click to select images below which you think contain Eastern Bluebird.
Remember that the color of the bird in a photo is sometimes slightly different from the illustrations.

[Click here to view detailed instructions.](#) Please read at least once.

[Select all](#) [Select none](#) Select images by clicking on them so that a green border appears.



[Select all](#) [Select none](#) Select images by clicking on them so that a green border appears.

[Click here to provide feedback on this HIT.](#) (Will expand this section to show a form.)

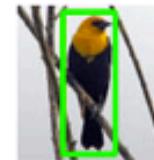
Tick this box if you are particularly interested in birds and consider yourself an expert on Eastern Bluebird (this will **not** affect your payment).



Photo by Chippewabear

Please draw a rectangle around the bird in the image. The rectangle should be fit around the bird tightly.

Good Rectangles:



Bad Rectangles:



Tick any of the boxes below if they are true about the image.

- Bird is **truncated**
- Bird is **occluded**
- There is **more than one bird**
- There is **no bird** in the image

1/5

◀ Previous

▶ Next

✓ Submit

Please provide feedback in the box below if you have comments:

Attribute Labeling

- attributes from whatbird.com
- 25 visual attributes \Rightarrow 288 binary attributes
 - similar to “dichotomous key” in biology
- MTurk interface
 - $\{guessing, probably, definitely\}$
- 5x redundancy factor



Attribute-Based Classification

- Number of attributes is less than number of classes
- Attribute classification tasks might be easier
- Makes it easier to incorporate human knowledge

Brewer's Sparrow *Spizella breweri*

Order PASSERIFORMES	Family Sparrows (Emberizidae)	Code 4 BRSP	Code 6 SPIBRE	ITIS 179440
BODY		HEAD		
				
<ul style="list-style-type: none">■ Length Range: 14 cm (5.5 in)■ Weight: 14 g (0.5 oz)■ Size: Small (5 - 9 in)■ Color Primary: Brown, Gray■ Underparts: Pale Gray■ Upperparts: Gray-brown with black streaking.■ Back Pattern: Striped or streaked■ Belly Pattern: Solid■ Breast Pattern: Solid		<ul style="list-style-type: none">■ Bill Shape: Cone■ Eye Color: Dark hazel or blackish brown at all ages.■ Head Pattern: Eyeline, Striped, Streaked, Eyering, Malar or malar stripe■ Crown Color: Gray-brown with fine black streaking.■ Forehead Color: Gray-brown with fine black streaking.■ Nape Color: Gray-brown with fine black streaking.■ Throat Color: White with gray wash.■ Cere color: No Data		
FLIGHT				

www.whatbird.com

You will be asked to answer a series of questions based on identifying visual features from the bird image on the left. Closely follow the specific instructions for each question. Holding the mouse over each selectable option for 1 second will provide additional instructions or examples.



What is the **pattern of the breast** of the bird? 1/12

Select one. If the breast isn't visible, make your best guess, then select "Guessing".



The question asks about the pattern of the bird's breast. A small illustration of a bird is shown with a red patch on its breast, indicating where the user should look for the pattern.

Solid Multi-Colored Striped Spotted

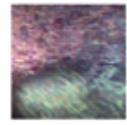
◀ Go Back ▶ Guessing ▶ Probably ▶ Definitely

You will be asked to answer a series of questions based on identifying visual features from the bird image on the left. Closely follow the specific instructions for each question. Holding the mouse over each selectable option for 1 second will provide additional instructions or examples.



What is the **color of the crown?** 1/12

Select at least one. If the crown isn't visible, make your best guess, then select "Guessing". If the color is a mixture of two colors, select both (e.g., for blue-green select blue and green). If the crown has two distinct colors, select both (e.g., for yellow with black stripes, select yellow and black).

White Black Grey Buff Brown
 Rufous Red Pink Orange Yellow
 Green Olive Blue Purple 
Shiny / Iridescent

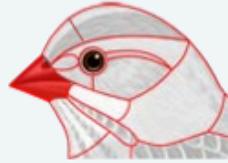
[Go Back](#) [Guessing](#) [Probably](#) [Definitely](#)

You will be asked to answer a series of questions based on identifying visual features from the bird image on the left. Closely follow the specific instructions for each question. Holding the mouse over each selectable option for 1 second will provide additional instructions or examples.



What is the **shape of the bill/beak?** 1/12

Select one. If the beak isn't visible, make your best guess, then select "Guessing".



The question asks about the shape of the bill/beak. The user can choose from eight options, each accompanied by a small image of a bird's head:

- All-purpose
- Cone
- Curved (up or down)
- Dagger
- Hooked
- Hooked Seabird
- Needle
- Spatulate
- Specialized

At the bottom are four navigation buttons:

- << Go Back
- > Guessing
- > Probably
- > Definitely

26

You will be asked to answer a series of questions based on identifying visual features from the bird image on the left. Closely follow the specific instructions for each question. Holding the mouse over each selectable option for 1 second will provide additional instructions or examples.



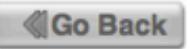
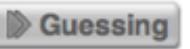
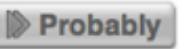
What is the **color of the wings** of the bird? 1/12

Select at least one. If the wings aren't visible, make your best guess, then select "Guessing". If the color is a mixture of two colors, select both (e.g., for blue-green select blue and green). If the wings have two distinct colors, select both (e.g., for yellow with black stripes, select yellow and black).

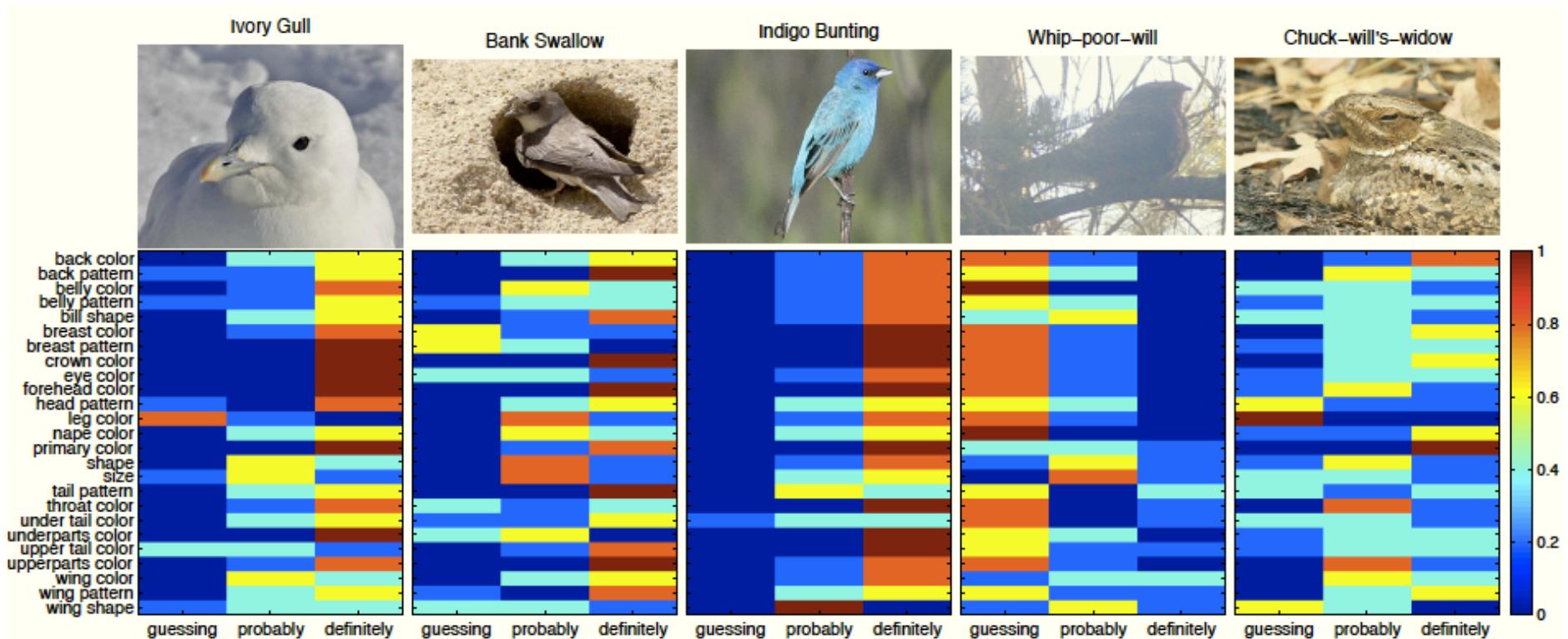
White Black Grey Buff Brown

Rufous Red Pink Orange Yellow

Green Olive Blue Purple 

MTurker Label Certainty



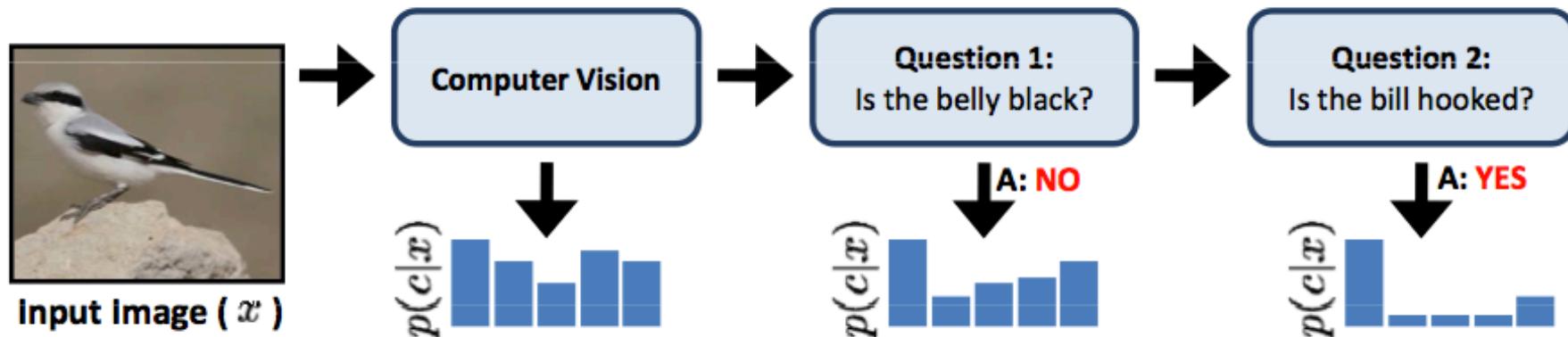
MTurker Feedback

- “These hits were fun. Will you be posting more of them anytime soon? Thanks!”
- “These are Beautiful birds and I am enjoying this hit collection”
- “I really enjoy doing your hits, they are fun and interesting. Thanks.”
- “Love doing these because I'm a bird watcher.”
- “the birds are so cute..hope u can send more kind of birds”
- “I haven't really studied birds, but doing these HITs has made me realize just how beautiful they are. It has also made me aware of the many different types of birds. Thank you”
- “I REALLY LOVE THE COLOR OF THE BIRDS.”
- “Thank you for providing this job. The fact that the images are beautiful to look at make it a lot more enjoyable to do!”
- “Enjoyable to do.”
- *Hourly Wage ≈ \$1.25*

Outline

- Visipedia project overview
- Relevant Work
- Birds-200 dataset
- **“Visual 20 Questions” game**
- Results
- Discussion

Visual 20 Questions



- “Computer Vision” module = Vedaldi’s *VLFfeat*
- VQ Geometric Blur, color/gray SIFT spatial pyramid
- Multiple Kernel Learning
- Per-Class 1-vs-All SVM
- 15 training examples per bird species
- Choose question to maximize expected Information Gain

Algorithm 1 Visual 20 Questions Game

- 1: $U^0 \leftarrow \emptyset$
- 2: **for** $t = 1$ to 20 **do**
- 3: $j(t) = \max_k I(c; u_k | x, U^{t-1})$
- 4: Ask user question $u_{j(t)}$, and $U^t \leftarrow U^{t-1} \cup u_{j(t)}$.
- 5: **end for**
- 6: Return class $c^* = \max_c p(c|x, U^t)$

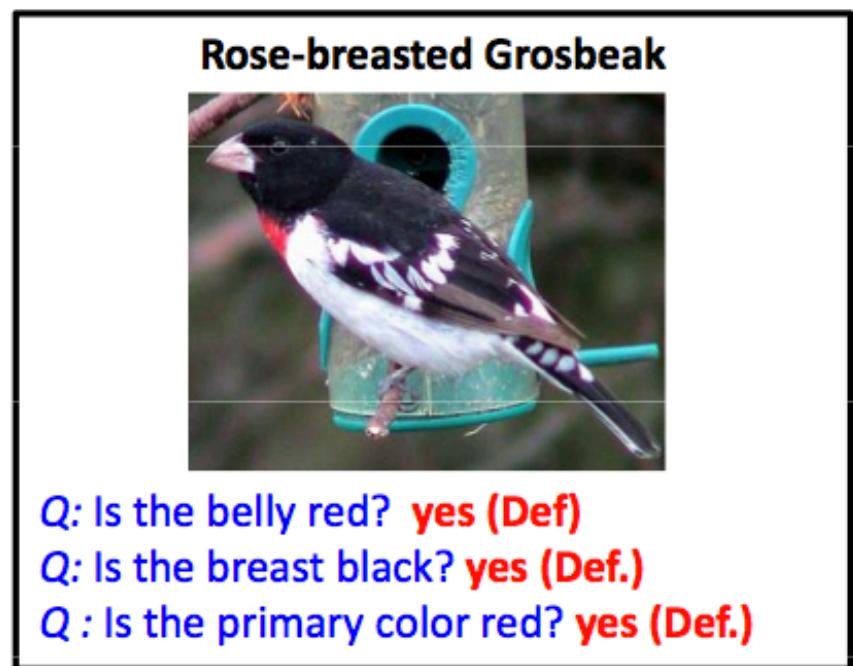
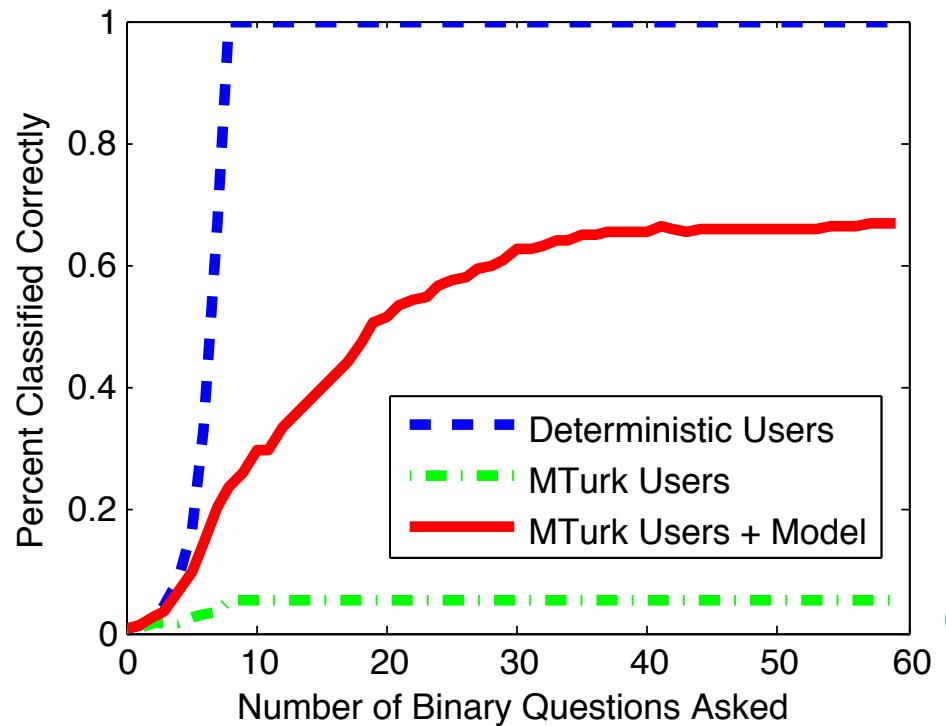
Outline

- Visipedia project overview
- Relevant Work
- Birds-200 dataset
- “Visual 20 Questions” game
- **Results**
- Discussion

General Observations

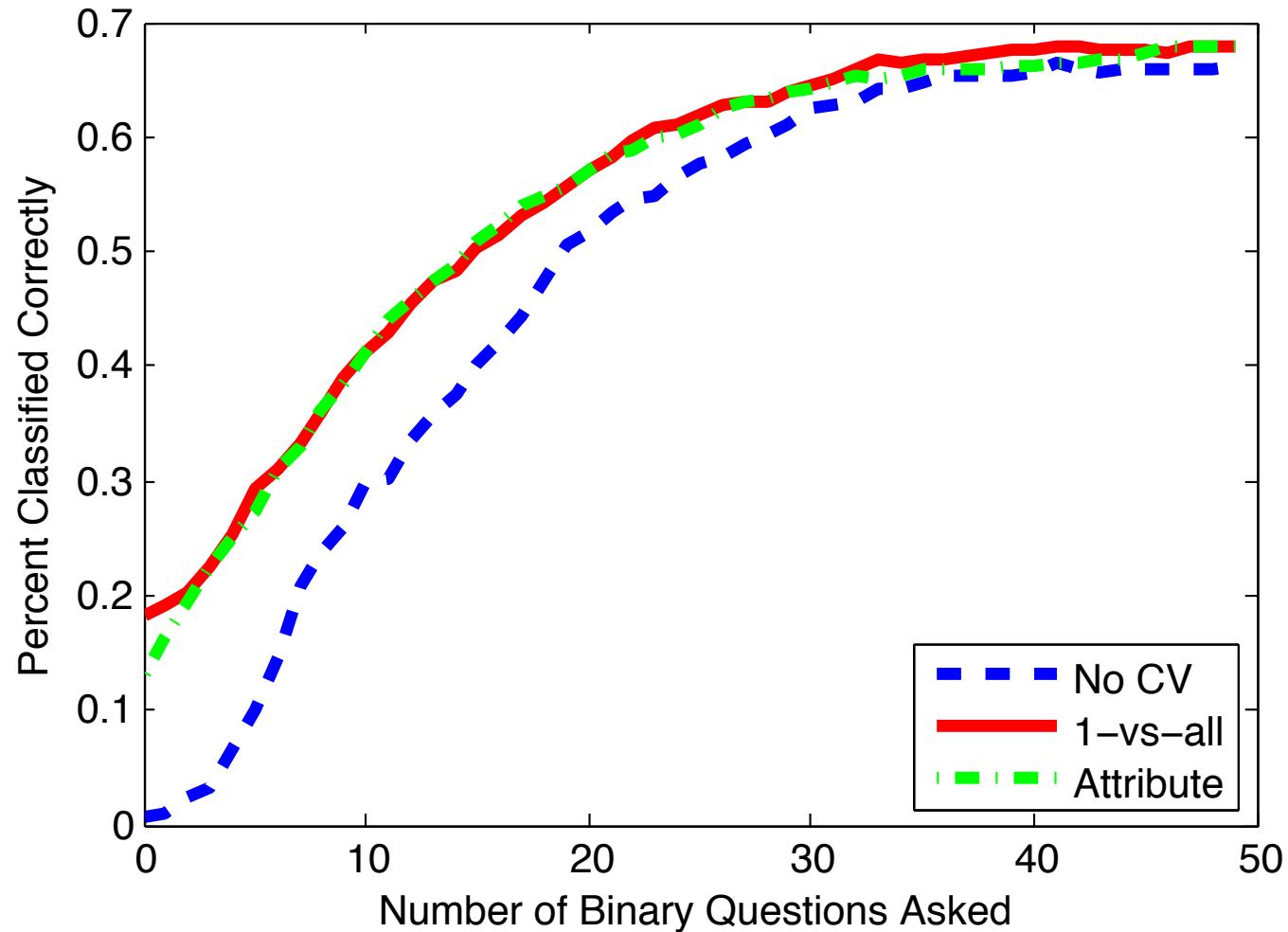
- User Responses are Stochastic
- Computer Vision Reduces Manual Labor
- User Responses Drive Up Performance
- Computer Vision Improves Overall Performance
- Different Questions are Asked w/ and w/o Computer Vision
- Recognition is not Always Successful

w/o Computer Vision



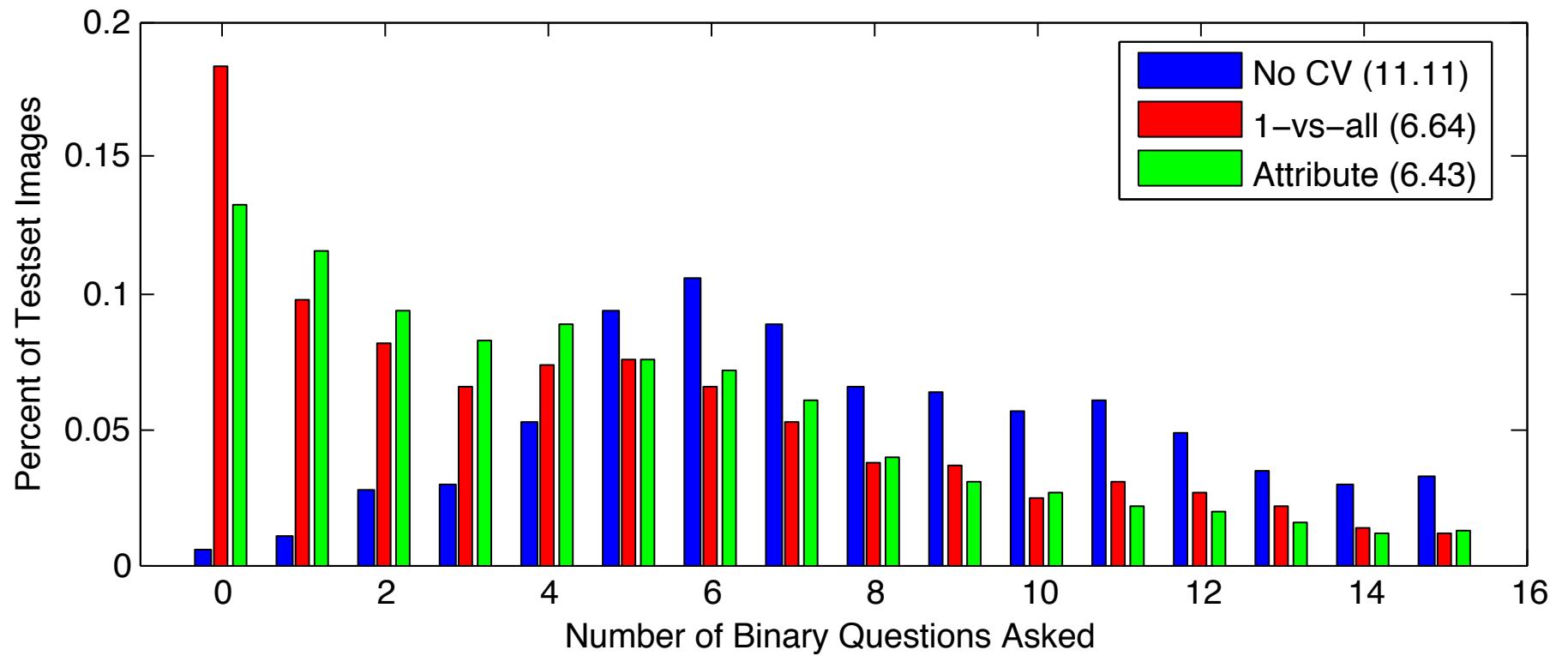
- User Responses are Stochastic

w/ Computer Vision



- Computer Vision Reduces Manual Labor

w/ Computer Vision (cont'd)



- User Responses Drive Up Performance

Western Grebe



w/ vision:
Q #1: Is the throat white? yes (Def.)

w/o vision:
Q #1: Is the shape perching-like? no (Def.)

Rose-breasted Grosbeak



Only CV →

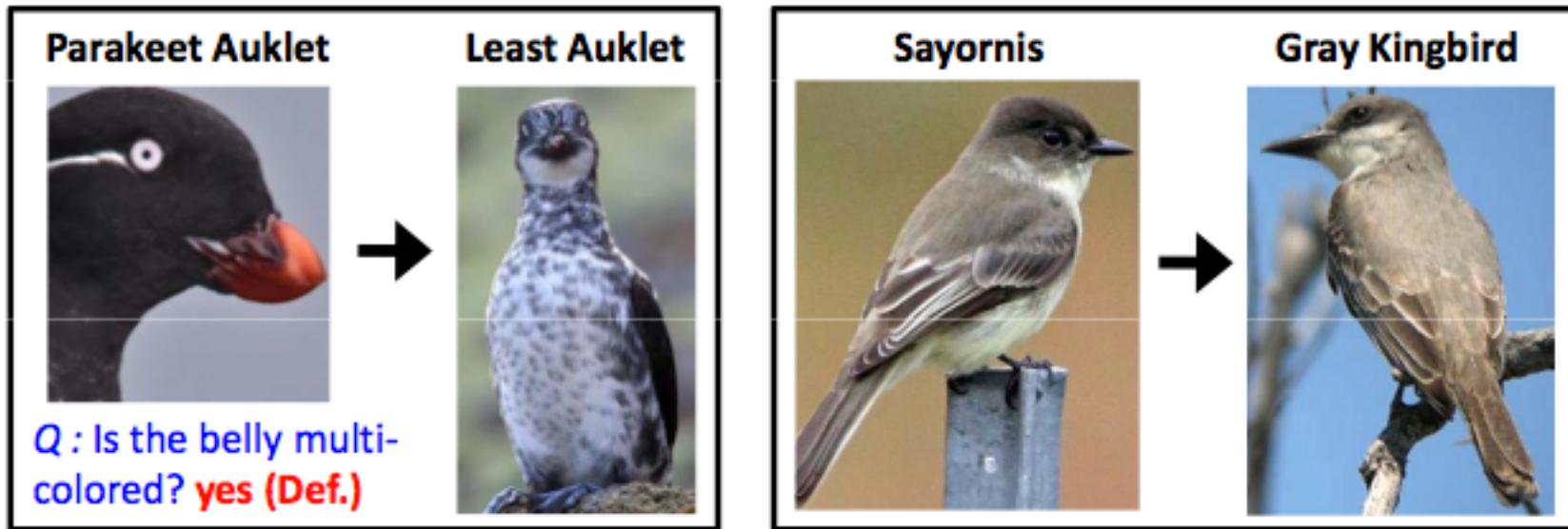
CV + Q #1:
Is the crown black? yes
(Def.)

Yellow-headed Blackbird



Rose-breasted Grosbeak

- Computer Vision Improves Overall Performance
- Different Questions are Asked w/ and w/o Computer Vision



- Recognition is not Always Successful

Indigo Bunting



Blue Grosbeak



Future Work

- More Birds! More Categories!
- Attribute Induction
- Incorporate Part Localization
- Partner with Wikimedia Foundation

