Apr. 10th, 2010, Workshop on Intelligent Systems: A Festschrift for Richard Volz , TAMU, College Station, TX

Collaborative Observation of Natural Environments (CONE)

Dezhen Song
Texas A&M University

NSF · Smithsonian · Microsoft · Panasonic · intel

Thanks to:

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Selma Glasscock, Welder Wildlife Foundation
National Science Foundation
The Nature Conservancy
Arkansas Game and Fish Commission
U.S. Fish and Wildlife Service
Arkansas Electric Cooperative
Cache River National Wildlife Refuge

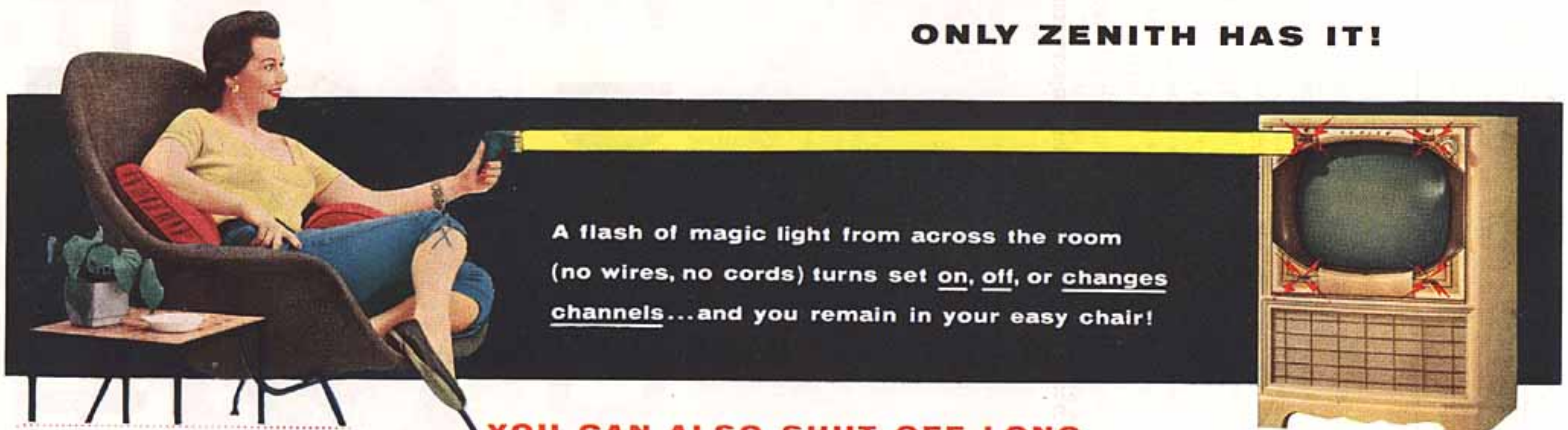
outline

- networked telerobots and project cone
- automated observation: ivory billed woodpecker
- engaging citizen scientists: bird range change in south texas

YOU HAVE TO SEE IT TO BELIEVE IT!

FLASH-MATIC TUNING BY ZENITH

ONLY ZENITH HAS IT!



With a beam of magic light

this Zenith "flash tuner" works TV miracles!

Absolutely harmless to humans!

YOU CAN ALSO SHUT OFF LONG, ANNOYING COMMERCIALS WHILE PICTURE REMAINS ON SCREEN!

Here is a truly amazing new television development—and only Zenith has it! Just think! Without budging from your easy chair you can turn your new Zenith Flash-Matic set *on, off, or change channels.* You can even *shut off annoying commercials* while the picture remains on the screen. Just a flash of light does it. There are no wires or cords. This is not an accessory. It is a built-in part of several new 1956 Zenith television receivers.

Stop at your Zenith dealer's soon. Zenith-quality television begins as low as $149.95.*

If it's new...it's from Zenith!

YOU HAVE TO SEE IT TO BELIEVE IT

**Manufacturer's suggested retail price. Slightly higher in Far West and South.*

The Bismarck **(Model X2264EQ).** 21", Flash-Matic Tuning, Cinébeam®, Ciné-Lens. Blond grained finish cabinet on casters. Also in mahogany color **(X2264RQ).** As low as $399.95.*

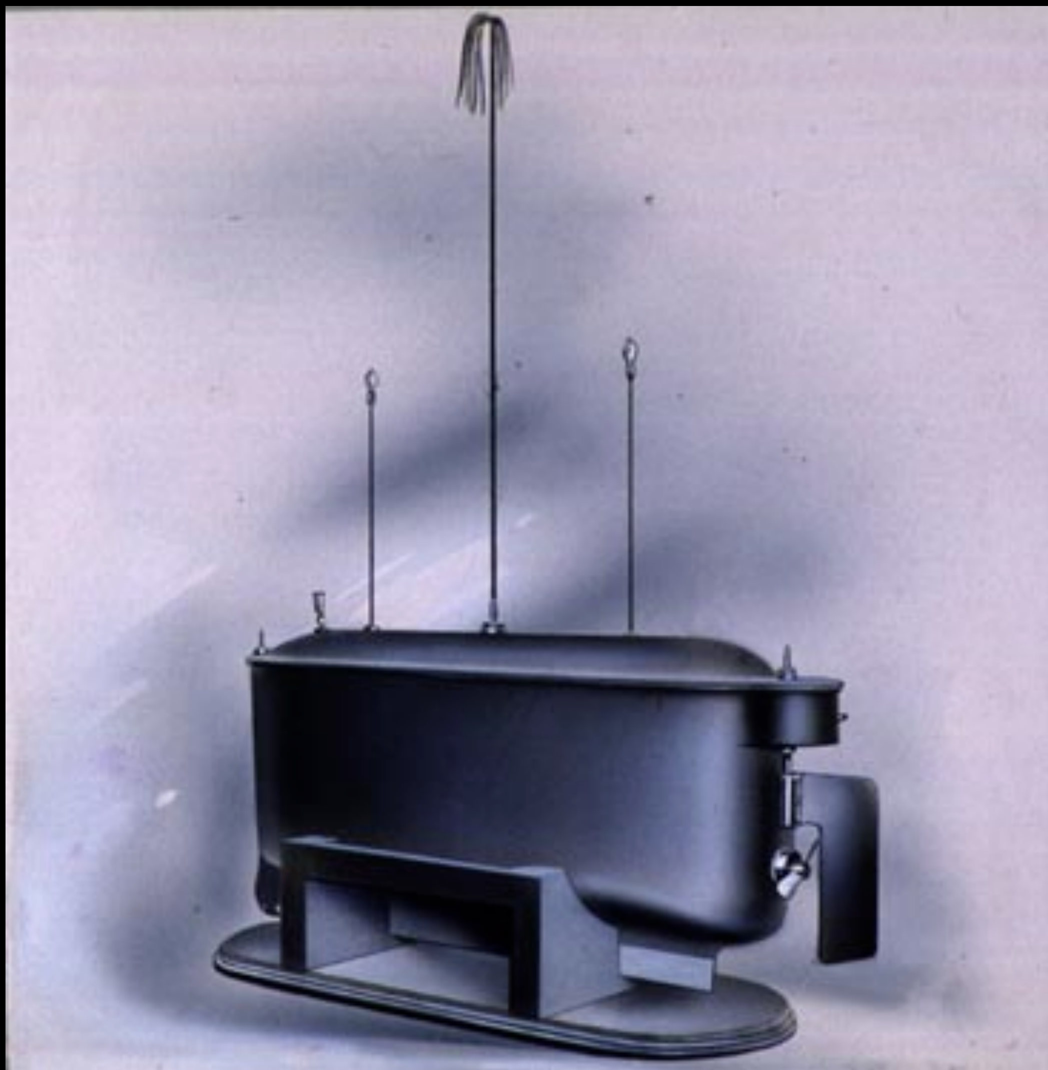
ZENITH®

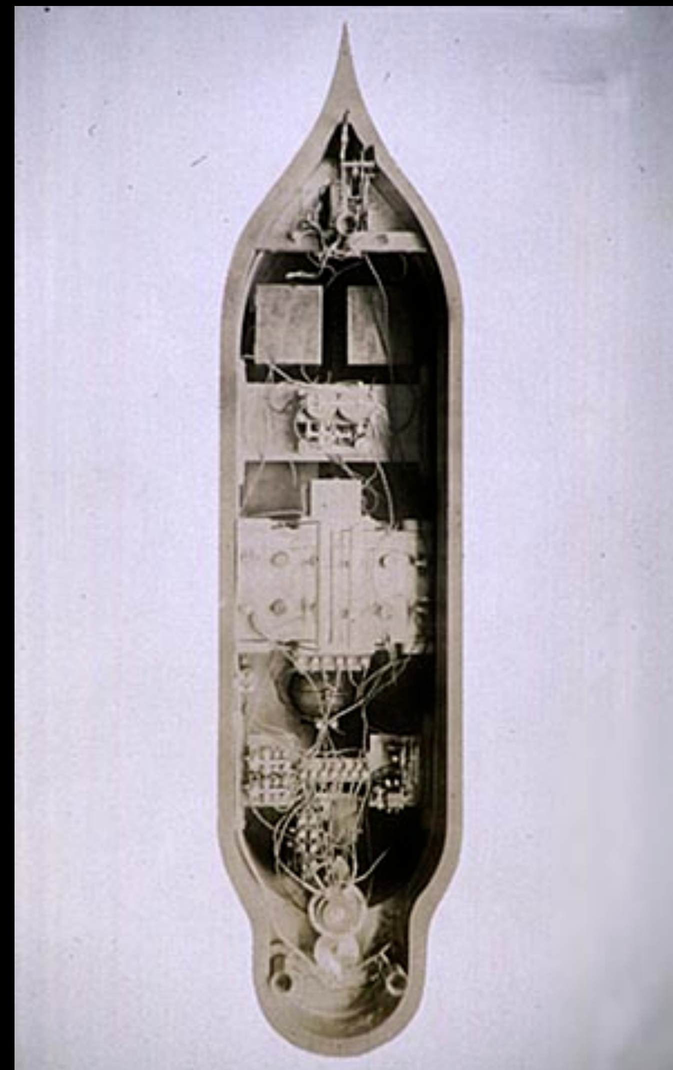
The royalty of TELEVISION and radio

Backed by 36 years of leadership in radionics exclusively

ALSO MAKERS OF FINE HEARING AIDS

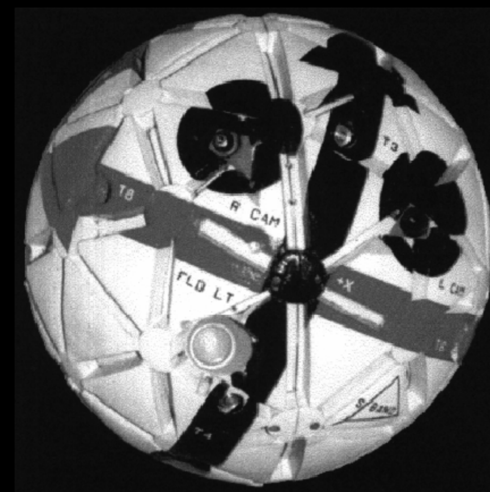
Zenith Radio Corporation, Chicago 39, Ill.





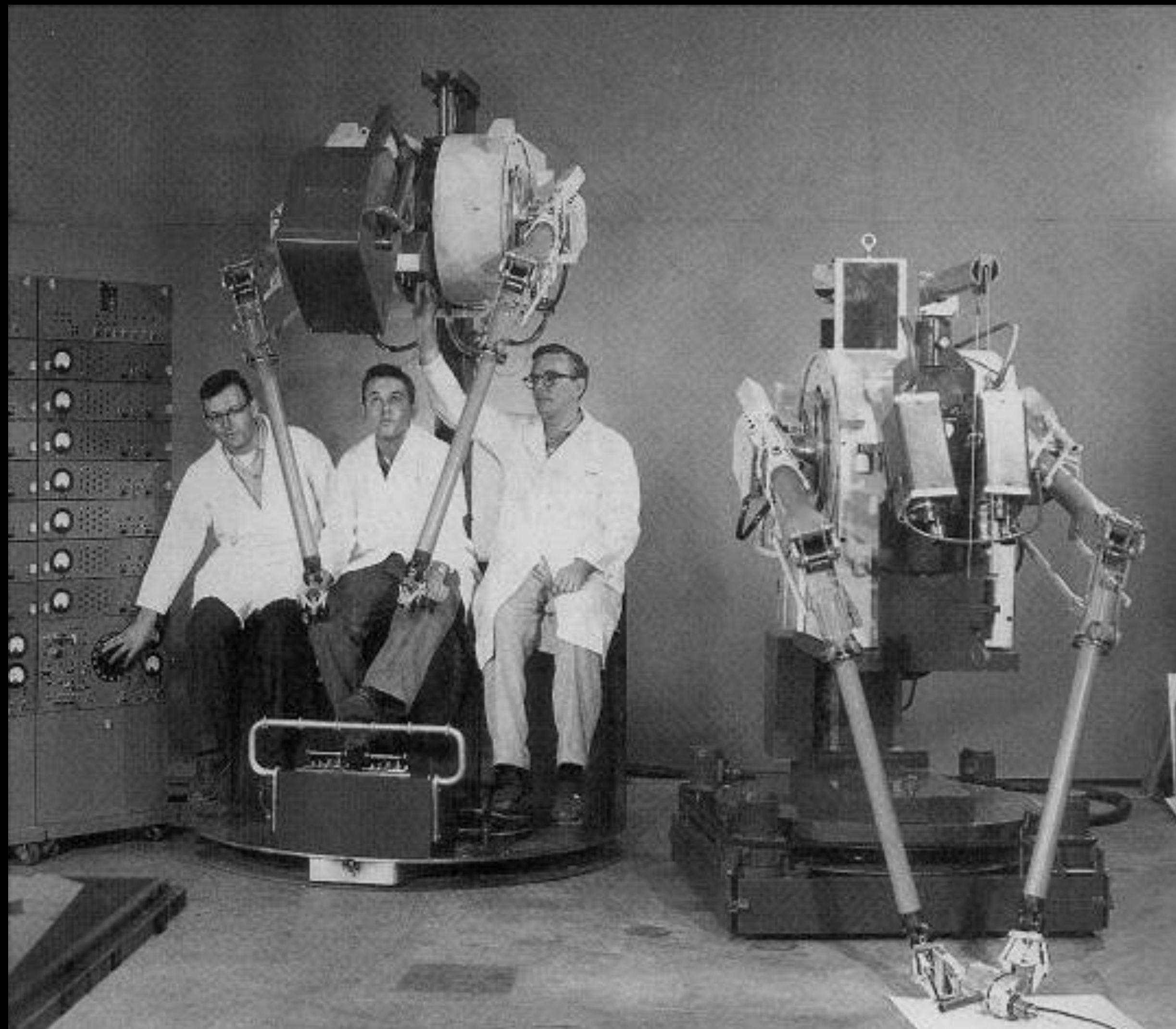
nikola tesla (1898)

teleoperation: related work



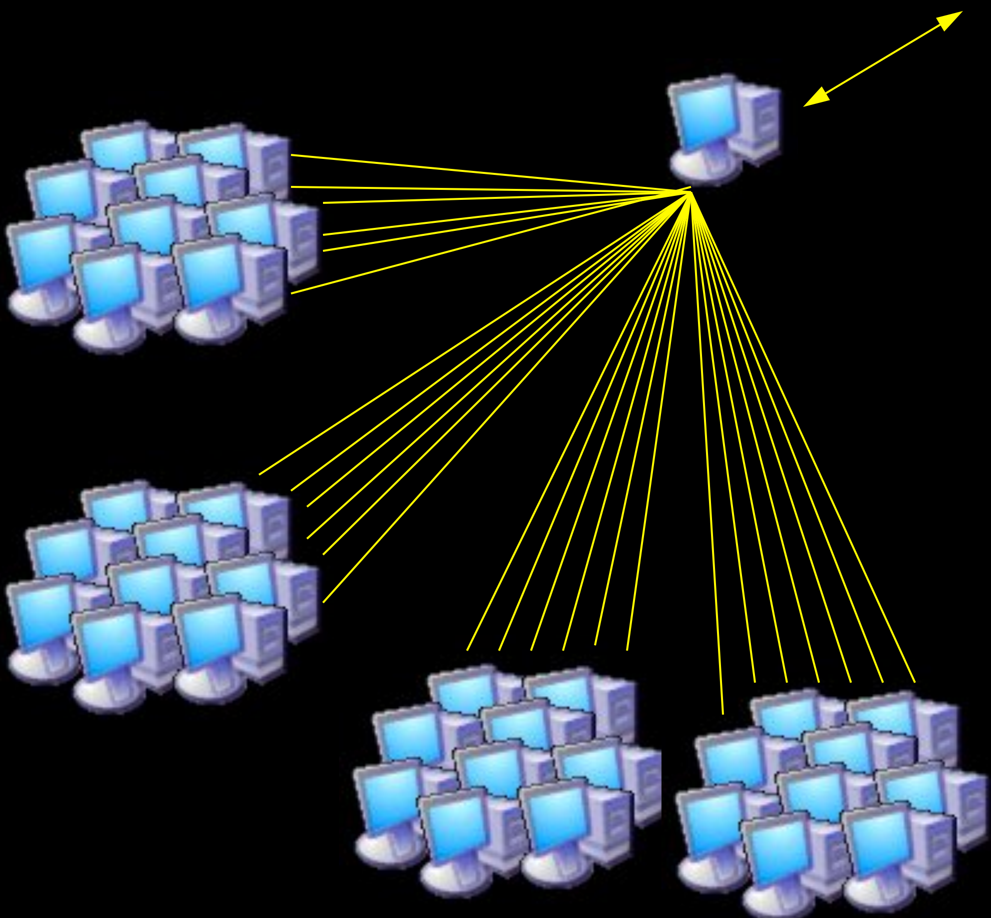
- Tesla, 1898
- Goertz, ‘54
- Mosher, ‘64
- Tomovic, ‘69
- Salisbury,Bejczy, ‘85
- Ballard, ’86
- Volz, ’87-
- Sheridan, ‘92
- Sato, ’94
- Goldberg, ’94-
- Presence Journal ‘92-
- O. Khatib, et al. ’96

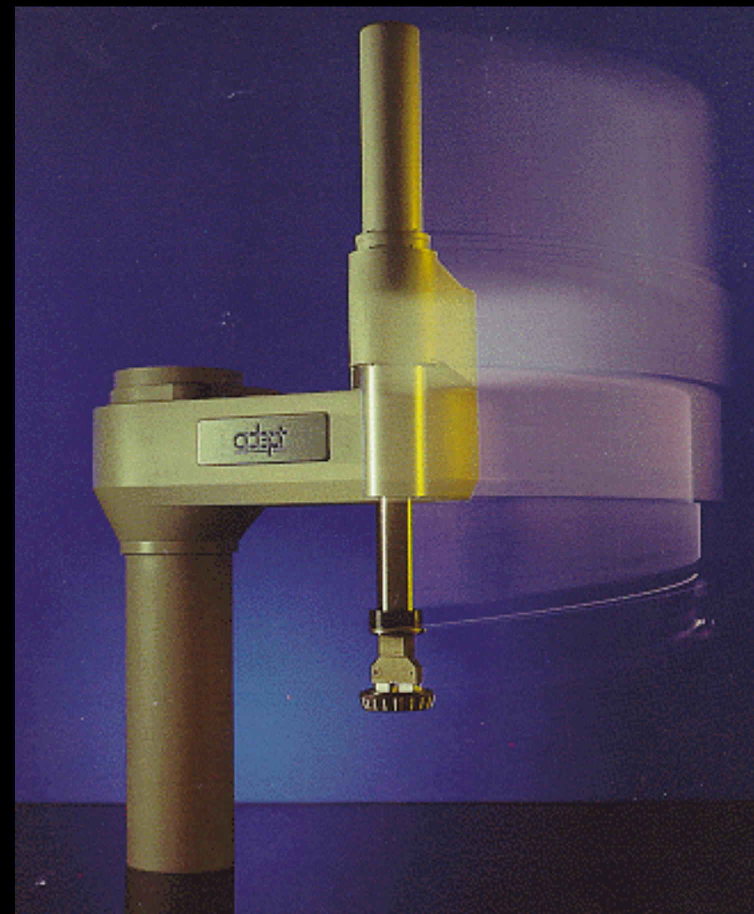

xcoffee



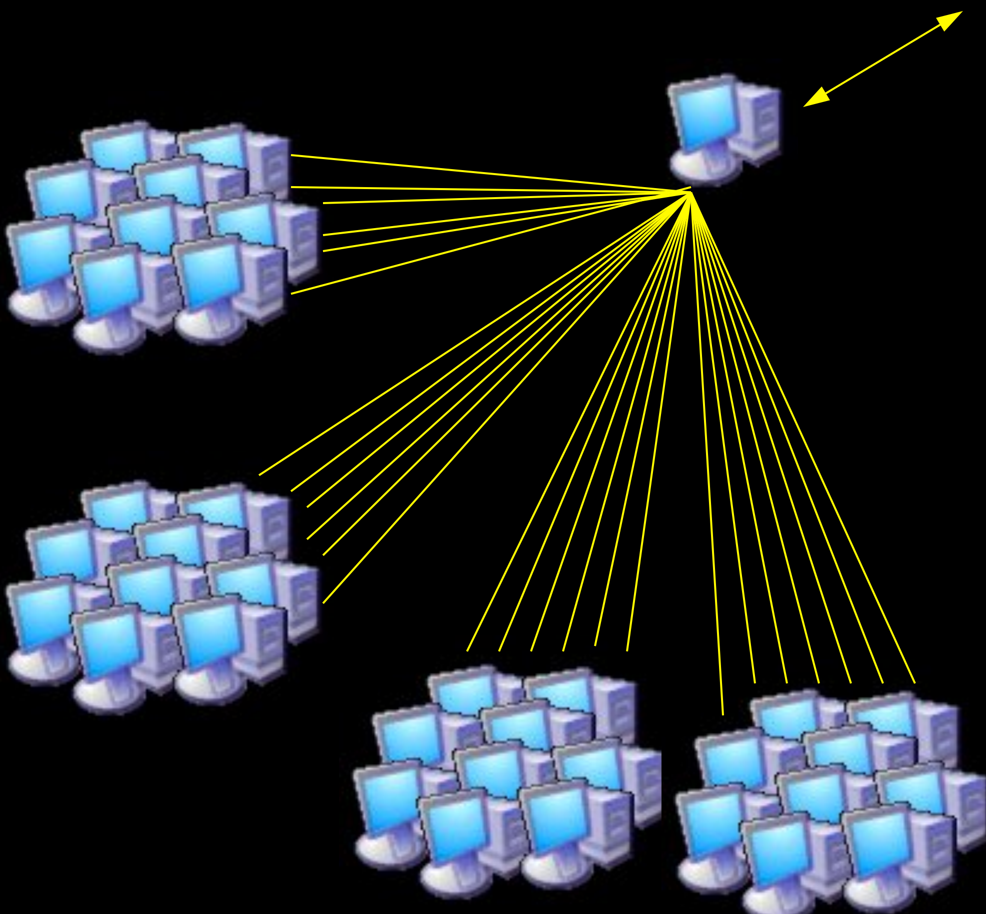
collaborative control

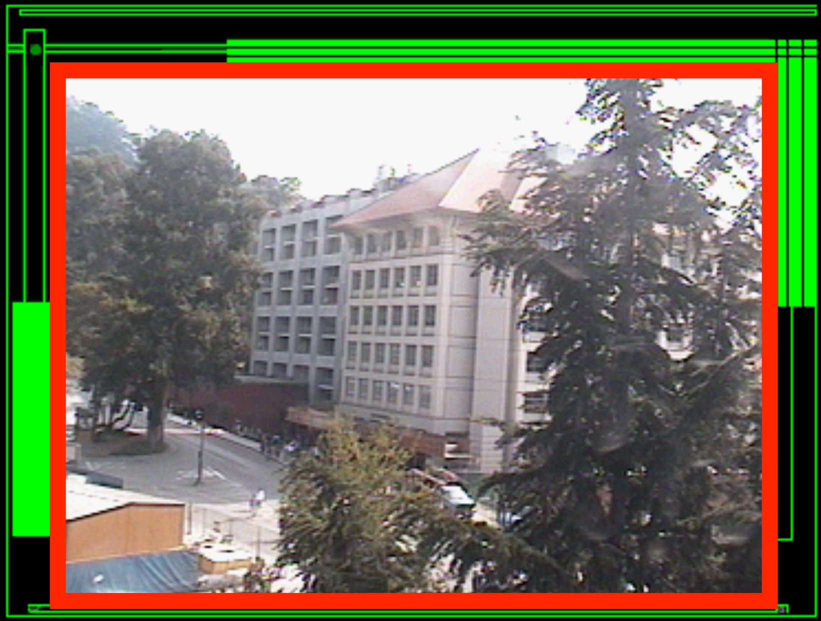
networked
telerobots





networked robotic camera

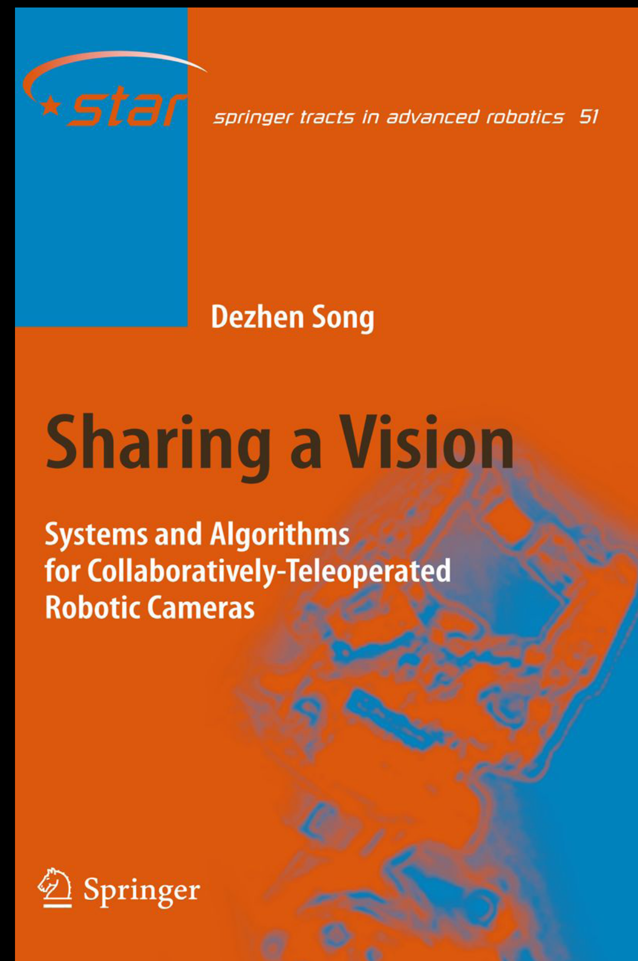




Frame Selection Problem: Given *n* requests, find optimal frame

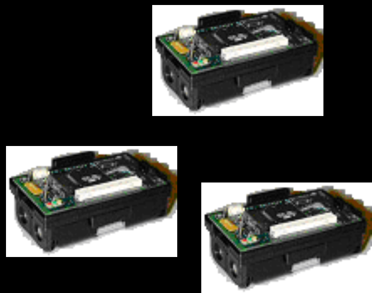
frame selection algorithms

Processing	Zoom	Type	Complexity
Centralized	Discrete	Exact	$O(n^2)$
Centralized	Discrete	Approx	$O(nk \log(nk))$, $k=(\log(1/\varepsilon)/\varepsilon)^2$
Centralized	Contin.	Exact	$O(n^3)$
Centralized	Contin.	Approx	$O((n + 1/\varepsilon^3) \log^2 n)$
Distributed	Discrete	Exact	Server: $O(n)$, Client: $O(n)$
Distributed	Contin.	Approx	Server: $O(n)$, Client $O(1/\varepsilon^3)$
p-Frame	Discrete	Approx	$O(n/\varepsilon^3 + p^2/\varepsilon^6)$



biological observation is arduous, expensive, dangerous, lonely

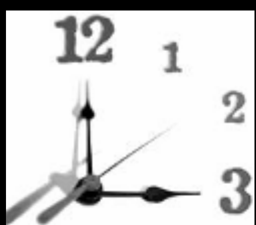
cone



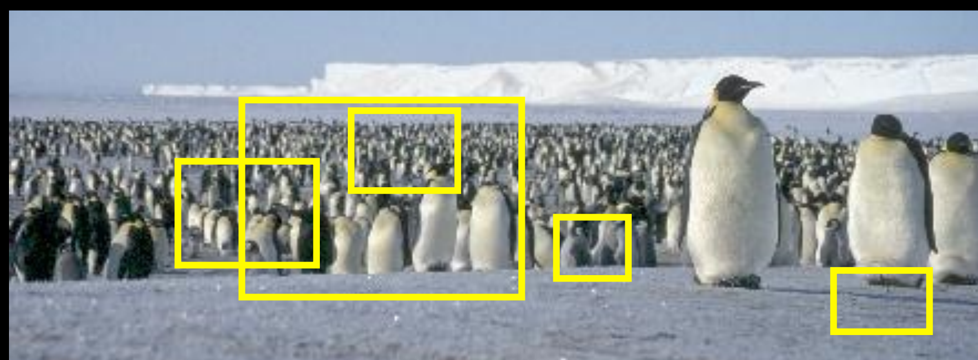
Sensor Network

Biologists

Collaborative frame selection:



Periodic Checks

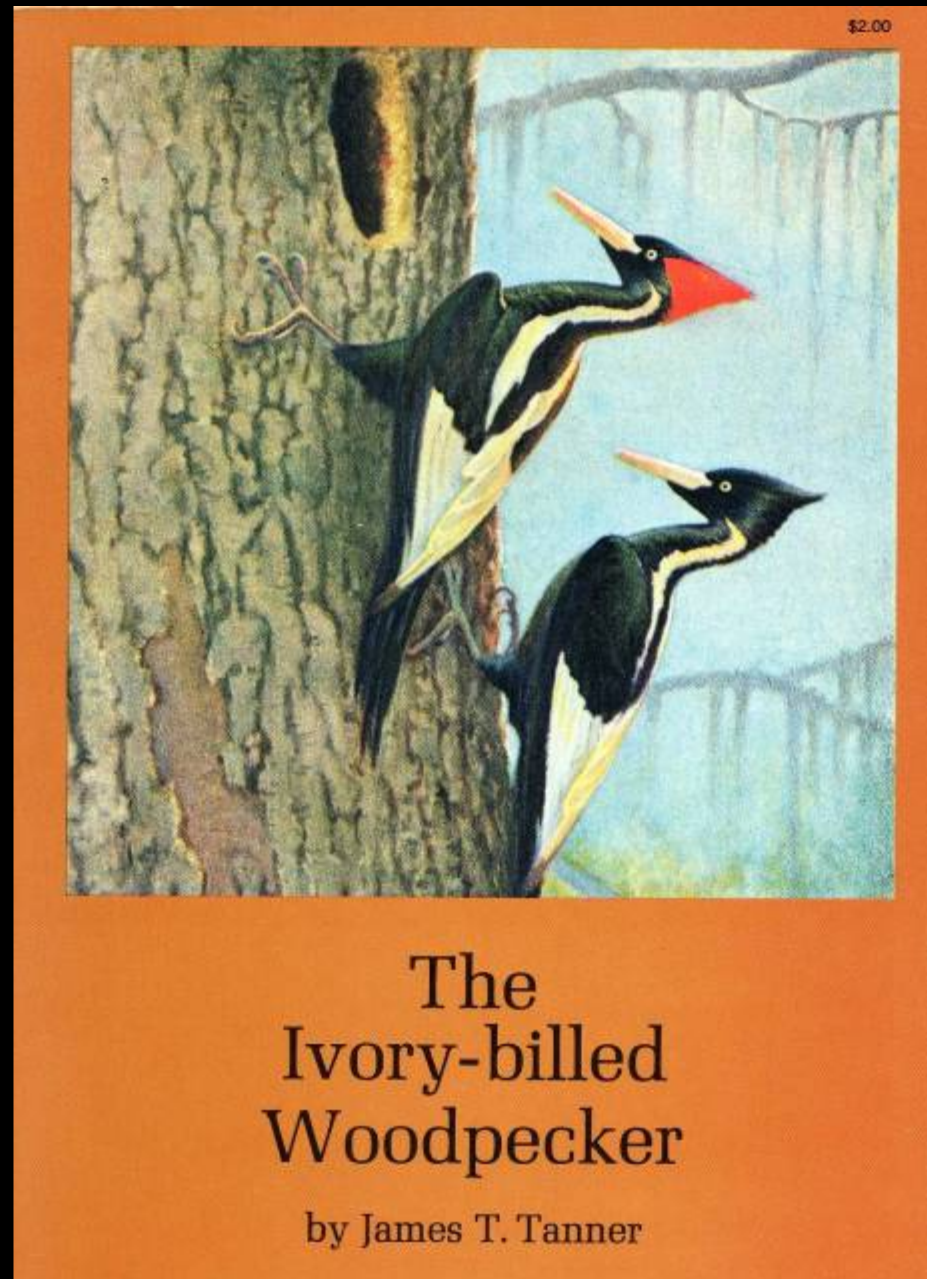


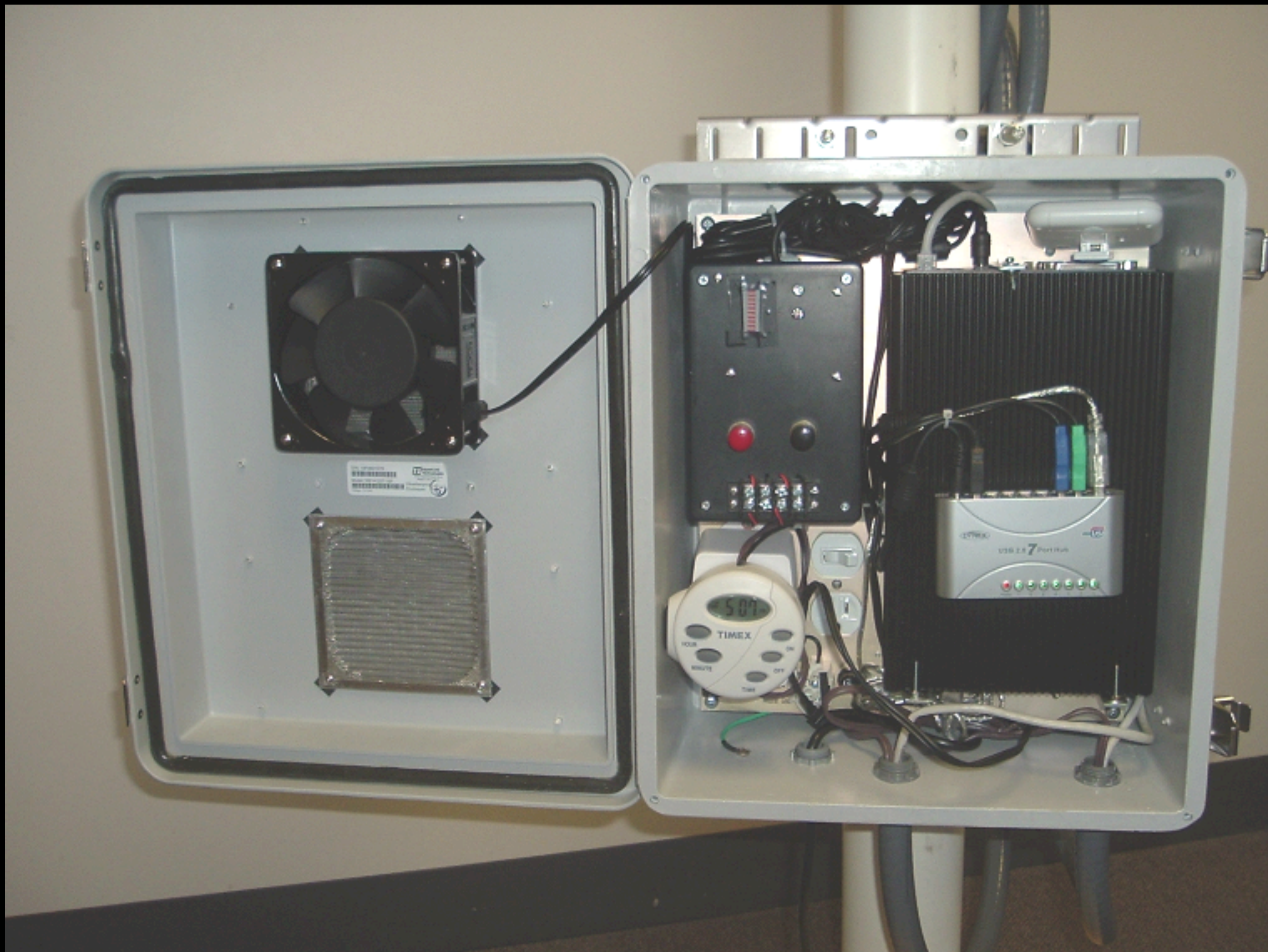
Motion Sensors

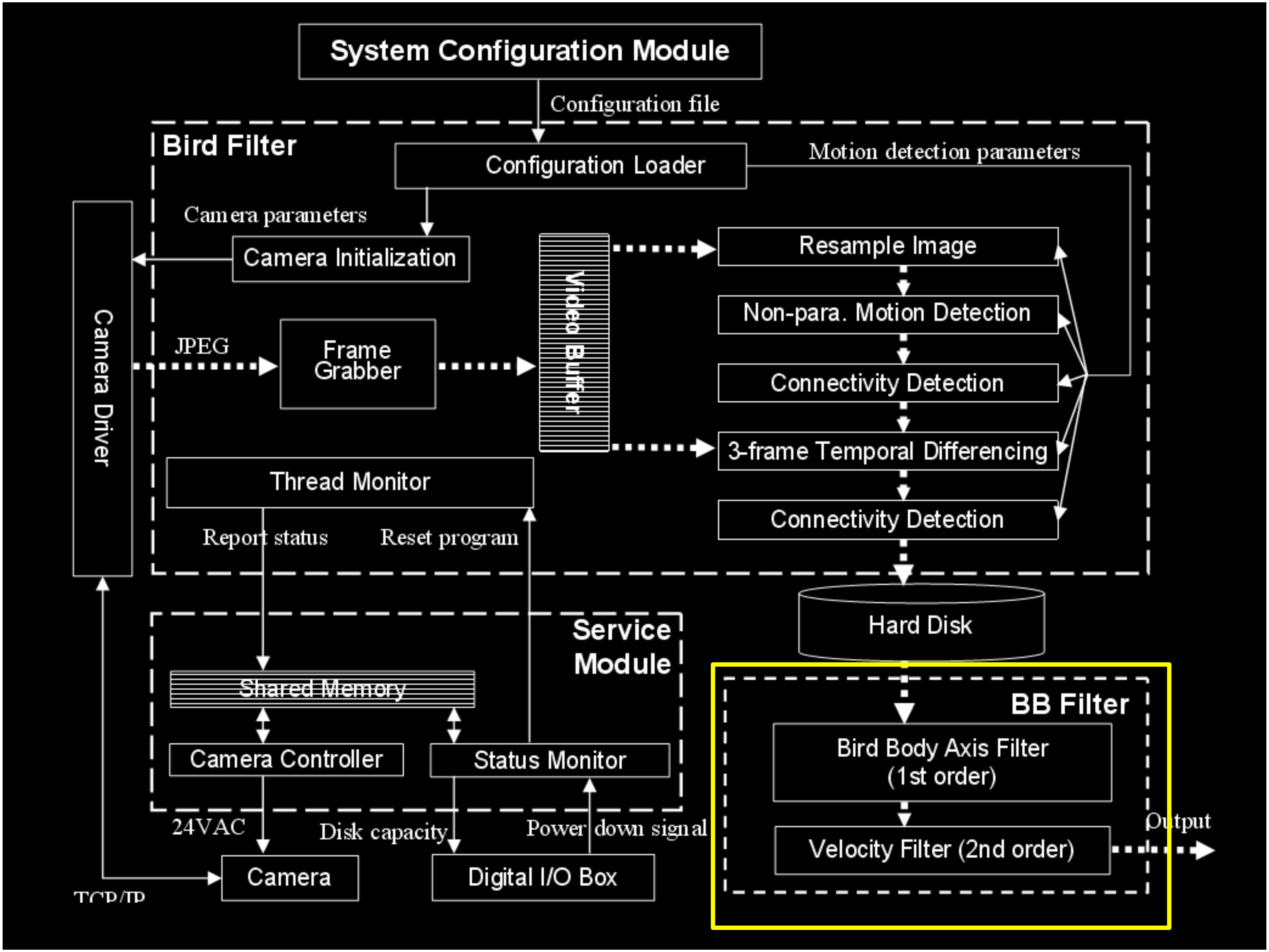
Students

outline

- networked telerobots and project cone
- automated observation: ivory billed woodpecker
- engaging citizen scientists: bird range change in south texas


$2.00
The
Ivory-billed
Woodpecker
by James T. Tanner


TIMEX



System Configuration Module
Configuration file
Bird Filter
Configuration Loader
Motion detection parameters
Camera parameters
Camera Initialization
Camera Driver
JPEG
Frame Grabber
Video Buffer
Resample Image
Non-para. Motion Detection
Connectivity Detection
3-frame Temporal Differencing
Connectivity Detection
Thread Monitor
Report status
Reset program
Hard Disk
Service Module
Shared Memory
Camera Controller
Status Monitor
BB Filter
Bird Body Axis Filter (1st order)
Velocity Filter (2nd order)
Output
24VAC
Disk capacity
Power down signal
Camera
Digital I/O Box
TCP/IP

Detecting Rare Birds

- Low occurrence (e.g., <10 times per year)
- Short duration (e.g., < 1 sec. in FOV)
- Huge video data for human identification.
- Setup and maintenance in remote environments.

Design Goals

- Accuracy
  - low false negative
- Data reduction
  - filtering the targeted bird
- Easy to setup and maintain
  - monocular vision system

Natural cameras

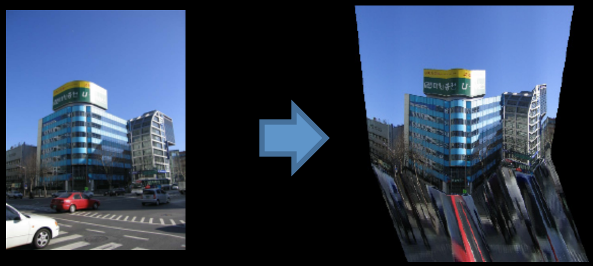
- Crittercam
- DeerCam
- Africa web cams at the Tembe Elephant part
- Tiger web cams
- James Reserve Wildlife Observatory
- Crane Cam
- Swan Cam

Related Work

- Motion detection and tracking
  - Elgammal, Grimson, Isard …

- Periodic motion detection
  - Culter, Ran, Briassouli …

- 3D inference using monocular vision
  - Ribnick, Hoiem, Saxena …



Related Work

- Kalman Filter
  - SLAM, tracking, recognition …
  - Convergence
    - ample observation data
    - manageable noise

- less than 11 data points
- significant image noise

Bird detection problem

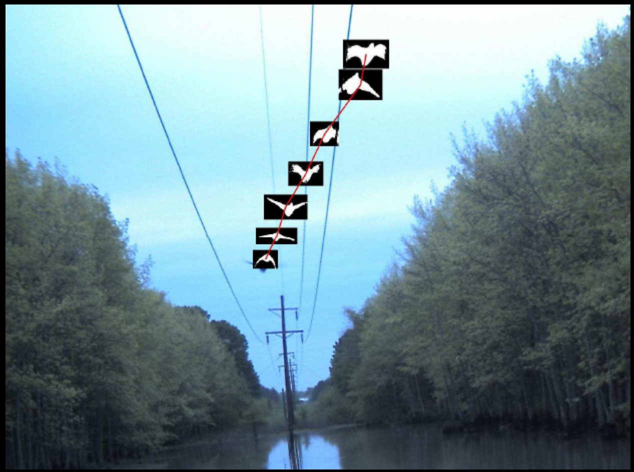
- Input
  - targeted bird body length l_b and speed range $\mathcal{V} = [v_{min}, v_{max}]$.
  - a sequence of n images containing a moving object

- Output
  - to determine if the object is a bird of targeted species

Assumptions

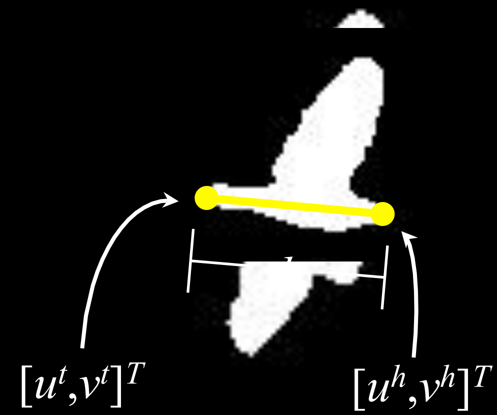
- Static monocular camera
  – High resolution
  – Narrow FOV

- Single bird in FOV
  – Motion segmentation
- Constant bird velocity
  – High flying speed
  – Narrow camera FOV



Conjecture 1: Invariant body length

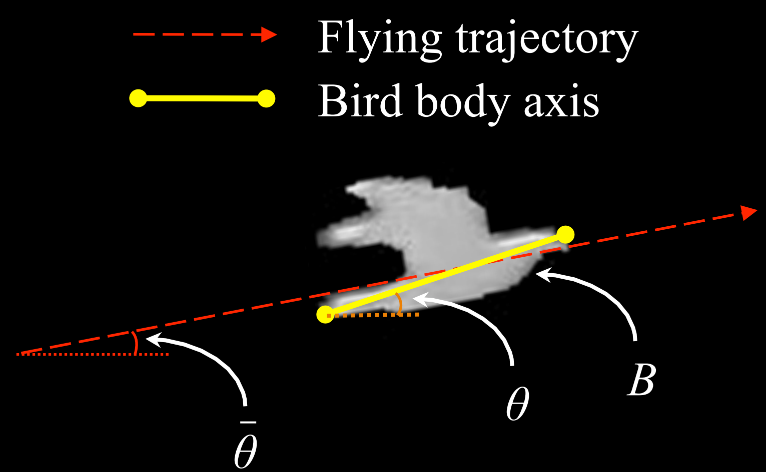
Conjecture 1: Invariant body length



$\mathbf{z}=[u^h, v^h, u^t, v^t]^T$ (observation)

Bird Body Axis Filtering

- Conjecture 2: Body axis orientation close to tangent line of trajectory

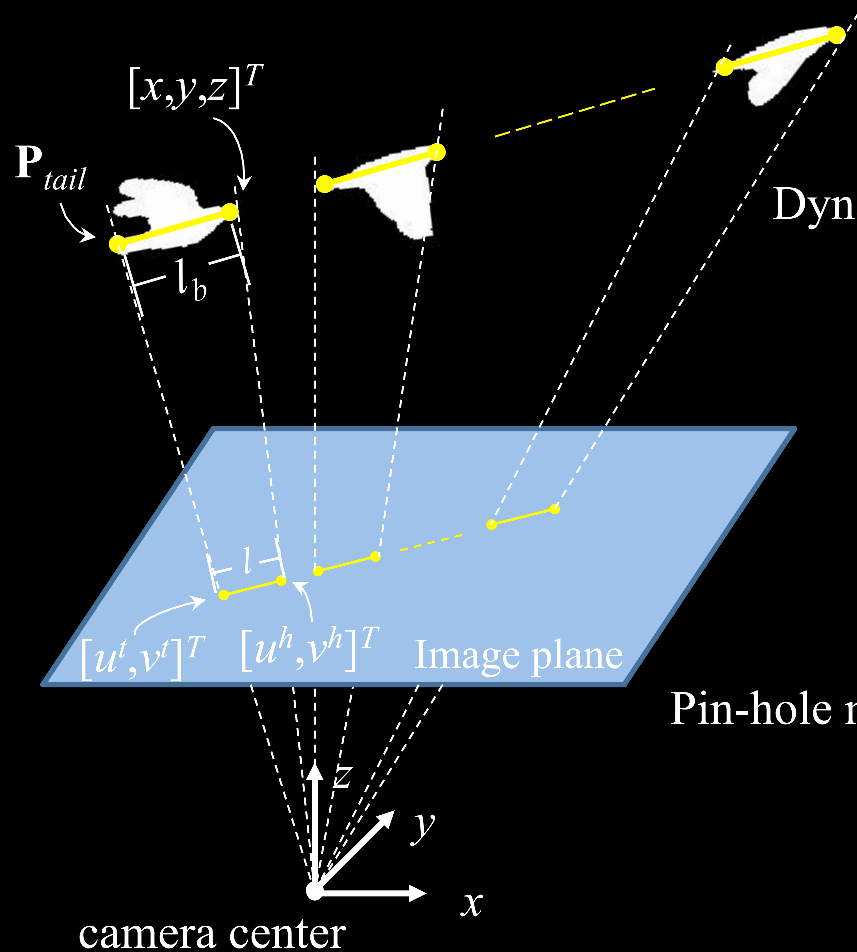


Difference between θ and $\bar{\theta}$ on 61bird sequences:

$$\mu_b = 0.8^\circ; \qquad \sigma_b = 8.3^\circ$$

$$z = \operatorname*{argmax}_{\substack{(u^h, v^h) \in B \\ (u^t, v^t) \in B}} l, \text{ s.t. } \theta \in [\bar{\theta} - 2\sigma_b, \bar{\theta} + 2\sigma_b]$$

Modeling A Flying Bird



$$\mathbf{p} = [x, y, z]^T \qquad \mathbf{v} = [\dot{x}, \dot{y}, \dot{z}]^T$$

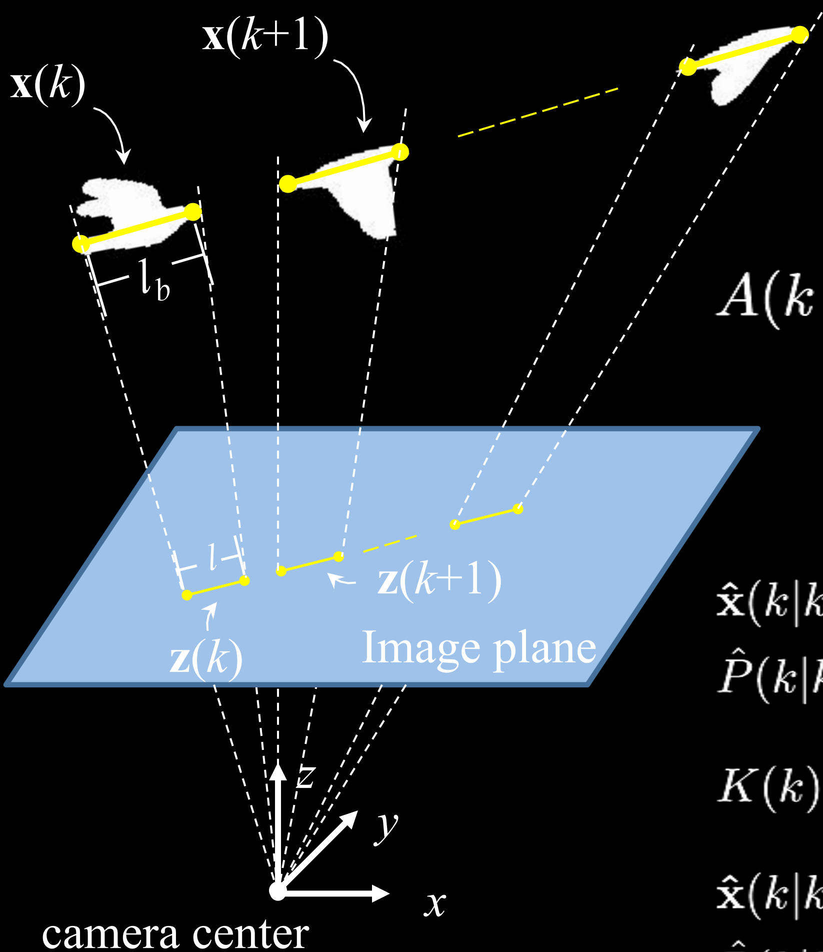
Dynamics: $\dot{\mathbf{x}} = \begin{bmatrix} \dot{\mathbf{p}} \\ \dot{\mathbf{v}} \end{bmatrix} = [\dot{x}, \dot{y}, \dot{z}, 0, 0, 0]^T = \begin{bmatrix} \mathbf{v} \\ \mathbf{0} \end{bmatrix}$

Tail: $\mathbf{P}_{tail} = [x^t, y^t, z^t]^T = \begin{bmatrix} x - \dot{x}l_b / \|\mathbf{v}\| \\ y - \dot{y}l_b / \|\mathbf{v}\| \\ z - \dot{z}l_b / \|\mathbf{v}\| \end{bmatrix}$

Pin-hole model: $\mathbf{z} = \begin{bmatrix} fx/z \\ fy/z \\ fx^t/z^t \\ fy^t/z^t \end{bmatrix} = \begin{bmatrix} fx/z \\ fy/z \\ f\frac{x\|\mathbf{v}\| - l_b\dot{x}}{z\|\mathbf{v}\| - l_b\dot{z}} \\ f\frac{y\|\mathbf{v}\| - l_b\dot{y}}{z\|\mathbf{v}\| - l_b\dot{z}} \end{bmatrix} + \mathbf{w}$

$$:= h(\mathbf{x}) + \mathbf{w}$$

Extended Kalman Filter

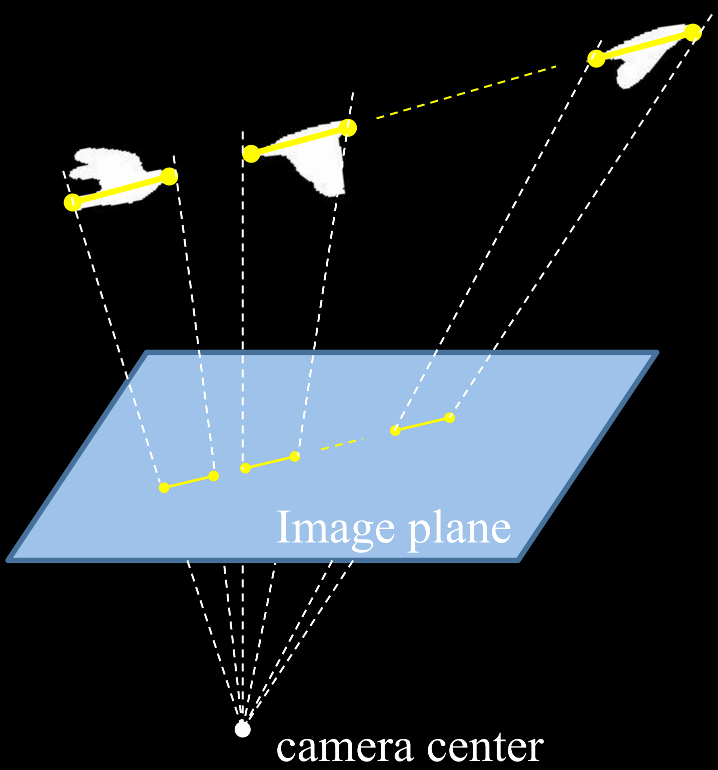


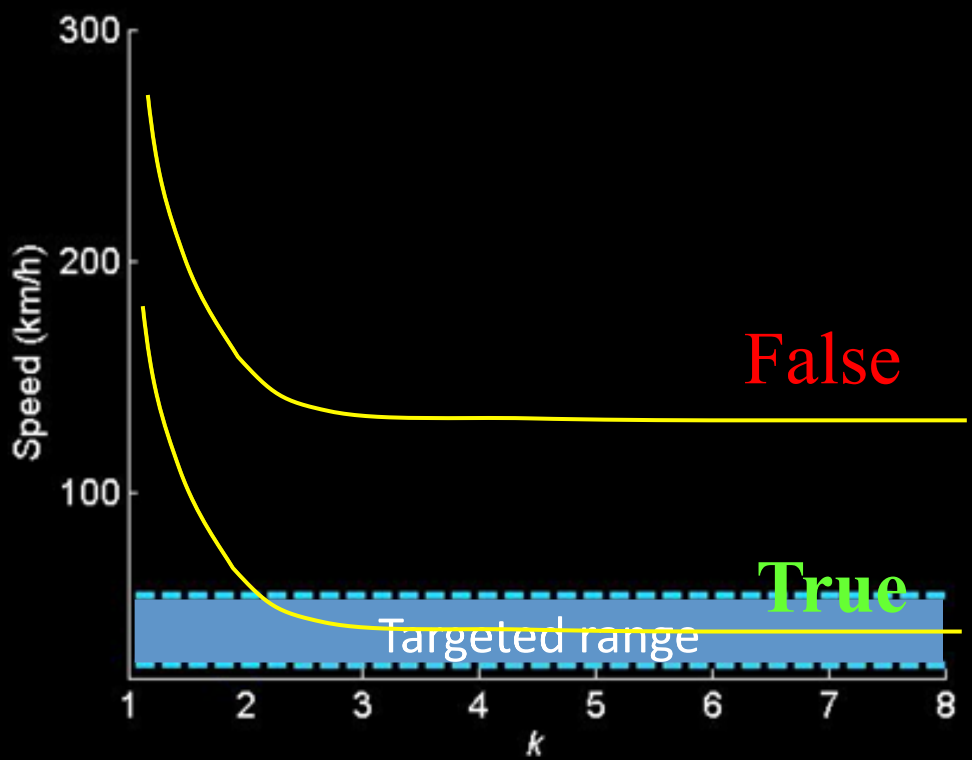
$$\mathbf{x}(k+1) = A(k+1)\mathbf{x}(k) + \mathbf{q}(k),$$
$$\mathbf{z}(k) = h(\mathbf{x}(k)) + \mathbf{w}(k),$$

$$A(k+1) = \begin{bmatrix} \mathbf{I}_{3\times3} & \Delta T(k+1|k)\mathbf{I}_{3\times3} \\ \mathbf{0}_{3\times3} & \mathbf{I}_{3\times3} \end{bmatrix}$$

$$\hat{\mathbf{x}}(k|k-1) = A(k)\hat{\mathbf{x}}(k-1|k-1),$$
$$\hat{P}(k|k-1) = A(k)\hat{P}(k-1|k-1)A^T(k) + Q(k),$$
$$K(k) = \frac{\hat{P}(k|k-1)H^T(k)}{H(k)\hat{P}(k|k-1)H^T(k) + W(k)},$$
$$\hat{\mathbf{x}}(k|k) = \hat{\mathbf{x}}(k|k-1) + K(k)(\mathbf{z}(k) - h(\hat{\mathbf{x}}(k|k-1))),$$
$$\hat{P}(k|k) = (\mathbf{I}_{6\times6} - K(k)H(k))\hat{P}(k|k-1),$$

Determine Species for Noise-free Cases





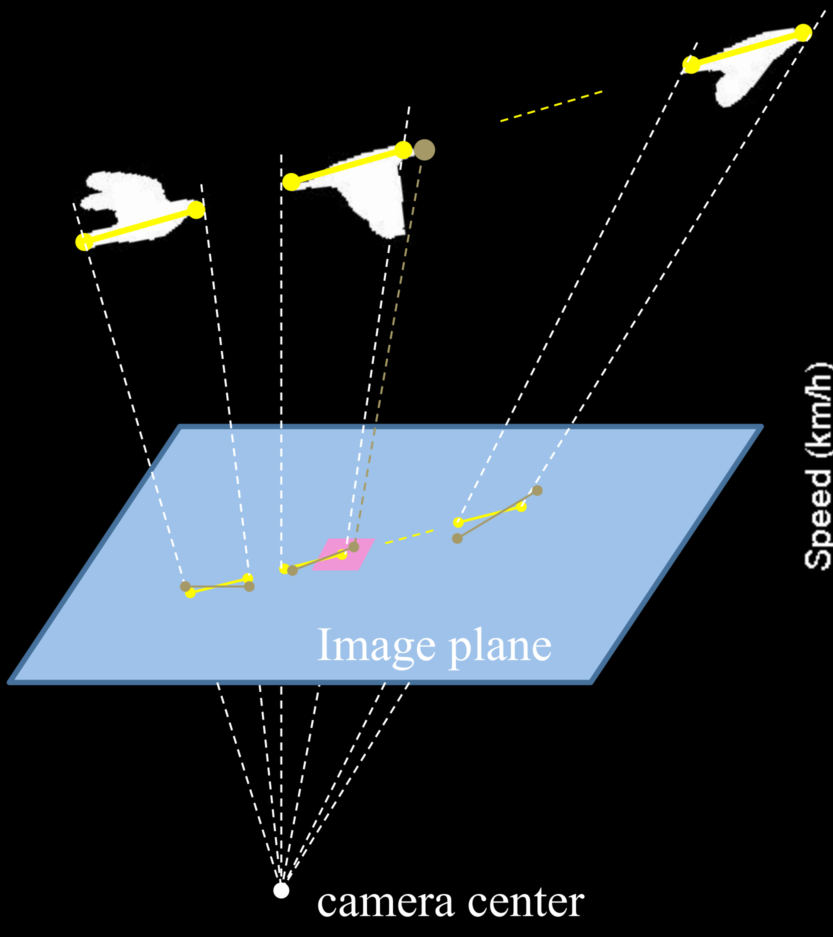
EKF Convergence Metrics

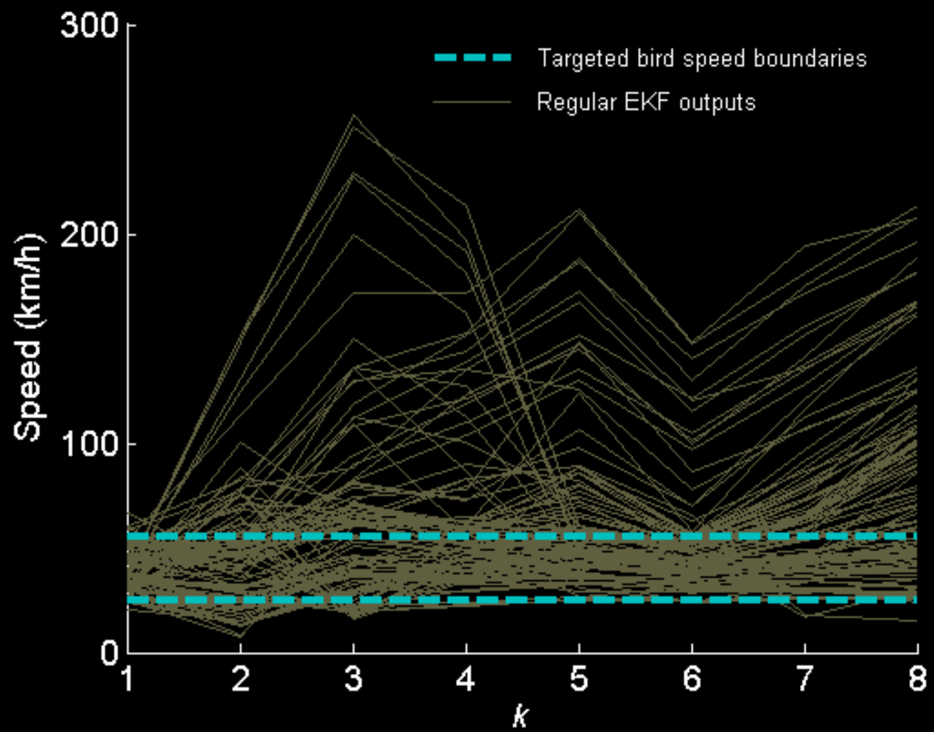
$$\text{EKF converges} \iff \|\hat{\mathbf{v}}(k|k) - \hat{\mathbf{v}}(k-1|k-1)\| \to 0$$

$$\varepsilon(\mathbf{X}^{1:n}) = \sum_{k=2}^{n} \omega(k) \|\hat{\mathbf{v}}(k|k) - \hat{\mathbf{v}}(k-1|k-1)\|$$

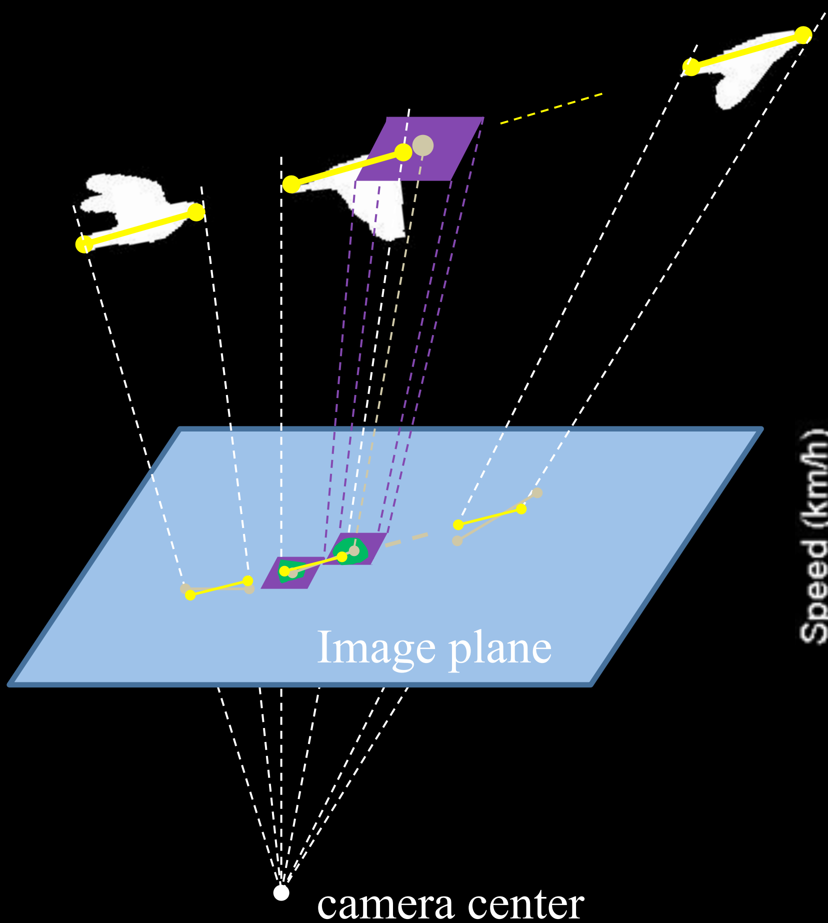
$$\omega(k) = E\left(\frac{\|\hat{\mathbf{v}}\|}{\|\hat{\mathbf{v}}(k|k) - \hat{\mathbf{v}}(k-1|k-1)\|} \right)$$

Estimation with Observation Noises





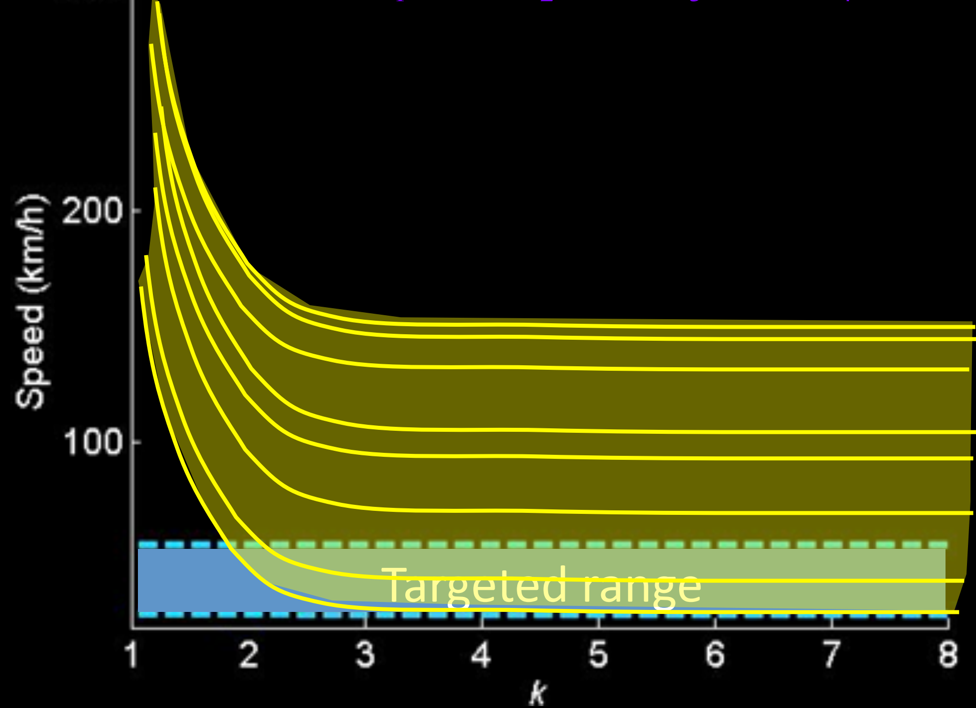
Probable Observation Data Set (PODS)



$S_1(k) = [u^h(k) \pm \tau]$ $S_2(k) = [v^h(k) \pm \tau]$

$S_3(k) = [u^t(k) \pm \tau]$ $S_4(k) = [v^t(k) \pm \tau]$

$\mathbf{S}(k) = S_1(k) \times S_2(k) \times S_3(k) \times S_4(k)$



$\varepsilon(\mathbf{X}^{1:n}) < \delta$

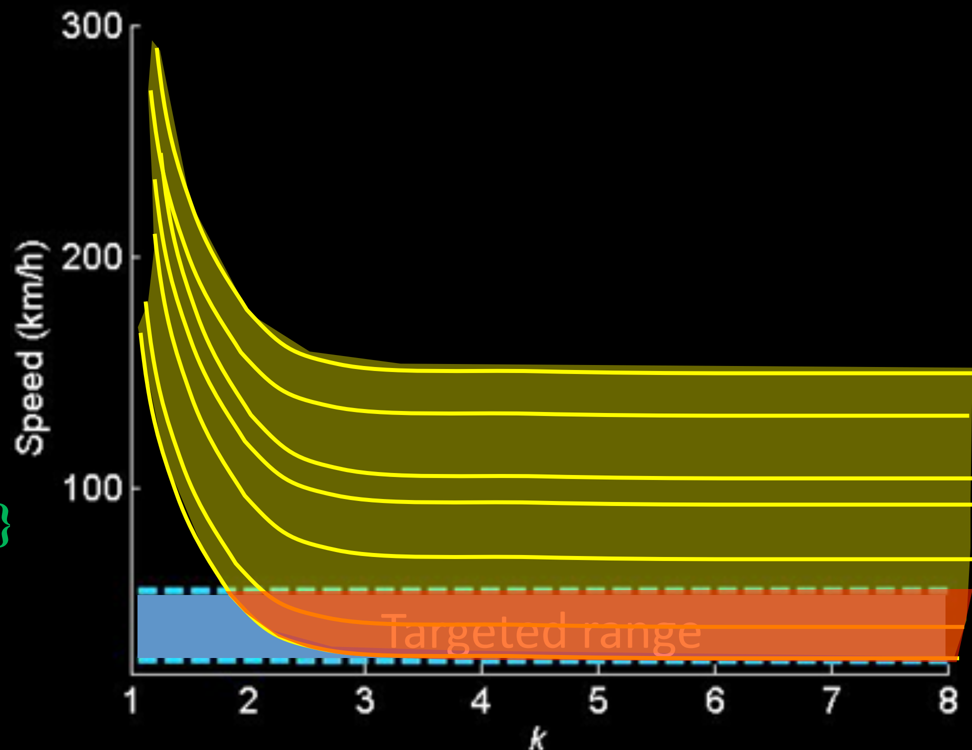
PODS-EKF

Decision-making:

$$I(\mathbf{Z}^{1:n}) = \begin{cases} 1 \text{ (accept) if } \mathbf{V} \cap \mathcal{V} \neq \Phi \text{ and } \mathbf{Z}^{1:n} \neq \Phi \\ 0 \text{ (reject) otherwise} \end{cases}$$

PODS:

$$\mathbf{Z}^{1:n} = \{\mathbf{Z}^{1:n} \mid \mathbf{z}(k) \in \mathbf{S}(k) \text{ and } \varepsilon(\mathbf{X}^{1:n}) < \delta\}$$



Dezhen Song and Yiliang Yu, *A Low False Negative Filter for Detecting Rare Bird Species from Short Video Segments using a Probable Observation Data Set-based EKF Method*, IEEE Transactions on Image Processing (Accepted, in press)

PODS-EKF Approximate Computation

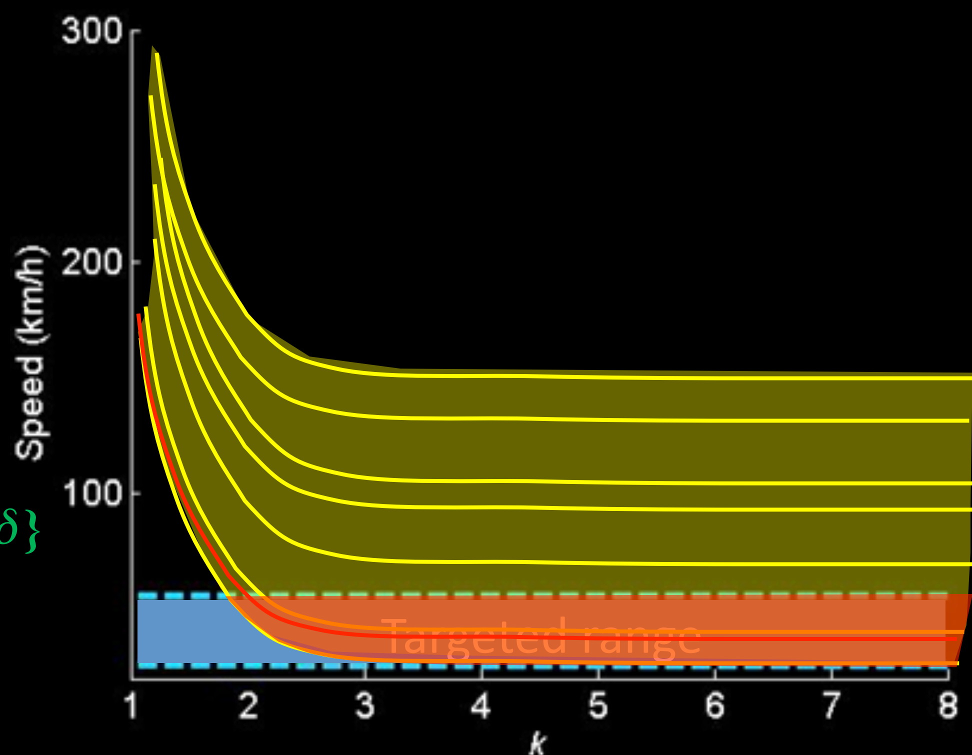
$$\tilde{\mathbf{Z}}^{1:n} = \arg\min_{\mathbf{z}(k)\in\mathbf{S}(k)} \varepsilon(\mathbf{X}^{1:n})$$

Subject to:

$$\hat{\mathbf{x}}(k|k-1) = A(k)\hat{\mathbf{x}}(k-1|k-1),$$
$$\hat{P}(k|k-1) = A(k)\hat{P}(k-1|k-1)A^T(k) + Q(k),$$
$$K(k) = \frac{\hat{P}(k|k-1)H^T(k)}{H(k)\hat{P}(k|k-1)H^T(k) + W(k)},$$
$$\hat{\mathbf{x}}(k|k) = \hat{\mathbf{x}}(k|k-1) + K(k)(\mathbf{z}(k) - h(\hat{\mathbf{x}}(k|k-1))),$$
$$\hat{P}(k|k) = (\mathbf{I}_{6\times 6} - K(k)H(k))\hat{P}(k|k-1),$$

$$\mathbf{Z}^{1:n} = \{\mathbf{Z}^{1:n} \mid \mathbf{z}(k)\in\mathbf{S}(k) \text{ and } \varepsilon(\mathbf{X}^{1:n}) < \delta\}$$

$$\|\tilde{\mathbf{v}}(n|n)\| \in \mathcal{V}$$



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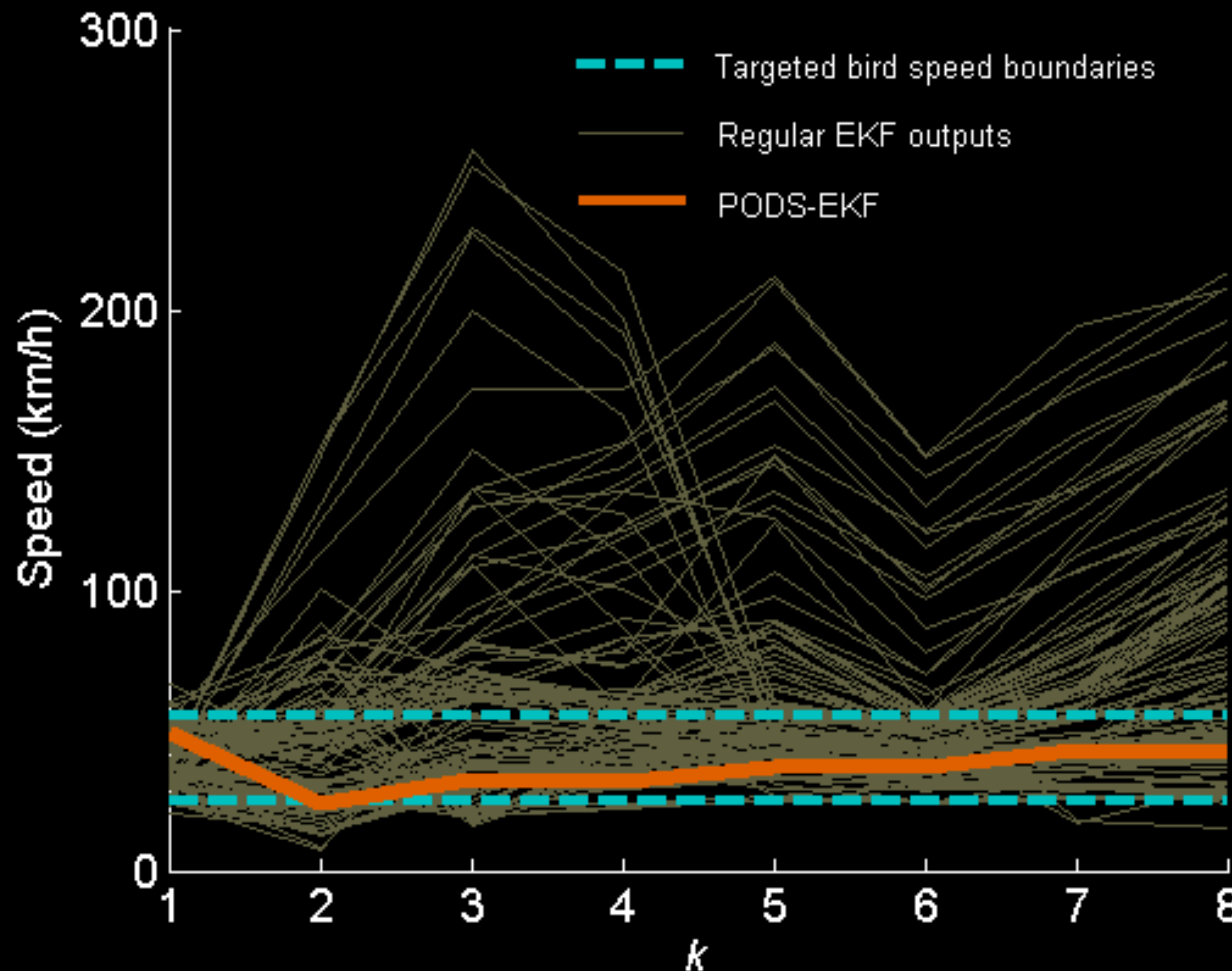


Dezhen Song and Yiliang Yu, *A Low False Negative Filter for Detecting Rare Bird Species from Short Video Segments using a Probable Observation Data Set-based EKF Method*, IEEE Transactions on Image Processing (Accepted, in press)

Algorithm

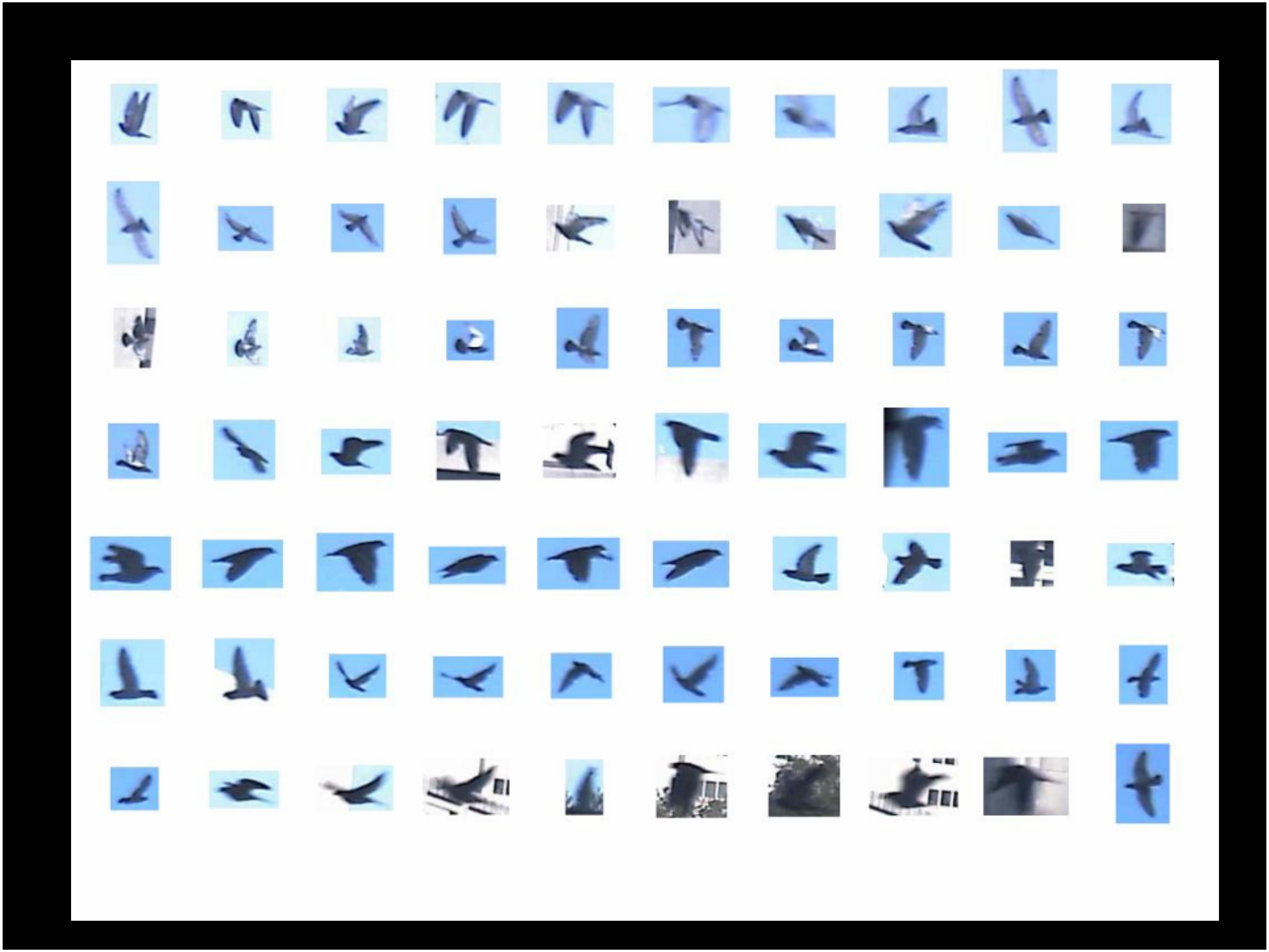
Algorithm 1: PODS-EKF based Bird Detection Algorithm

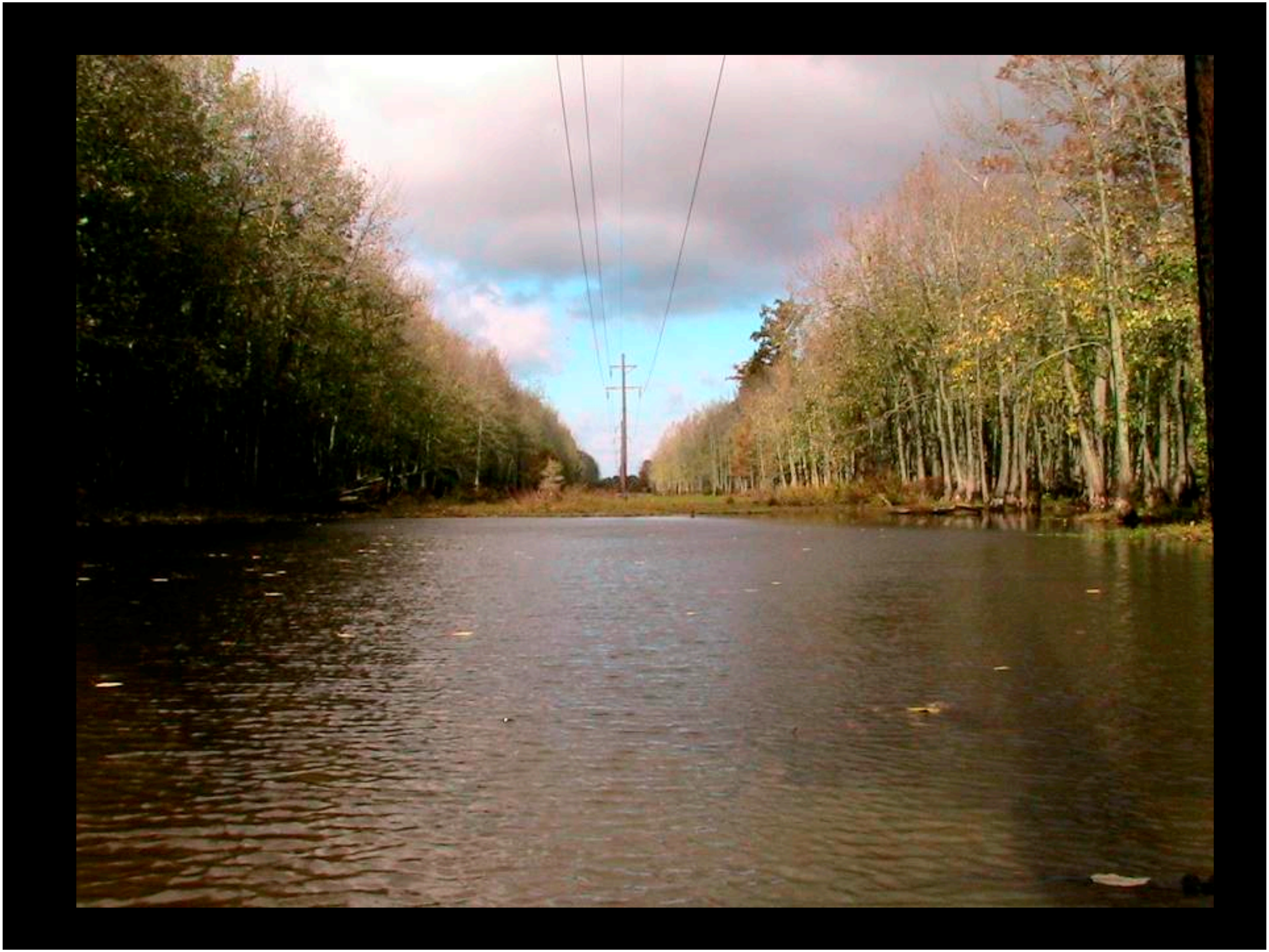
input : n frames with a segmented motion sequence
output: TRUE or FALSE for the targeted species.
for *the segmented motion block in i-th frame* **do**
  calculate the geometric center point C_i of the bird;
Connect $C_i,\ i = 1, 2, ..., n$ to generate a piecewise linear trajectory;
Obtain $\bar{\theta}$ from the trajectory;
for *the segmented motion block in i-th frame* **do**
  Obtain $\mathbf{z}(i)$ using the BBAF in (2);
Initialize the EKF using (20) and (21);
Solve the constrained nonlinear optimization problem in (14);
if $\|\widetilde{\mathrm{v}}(n|n)\| \in \mathcal{V}$ ***AND*** $\varepsilon(\widetilde{\mathrm{X}}^{1:n}) < \delta$ **then**
  return TRUE;
else
  return FALSE;

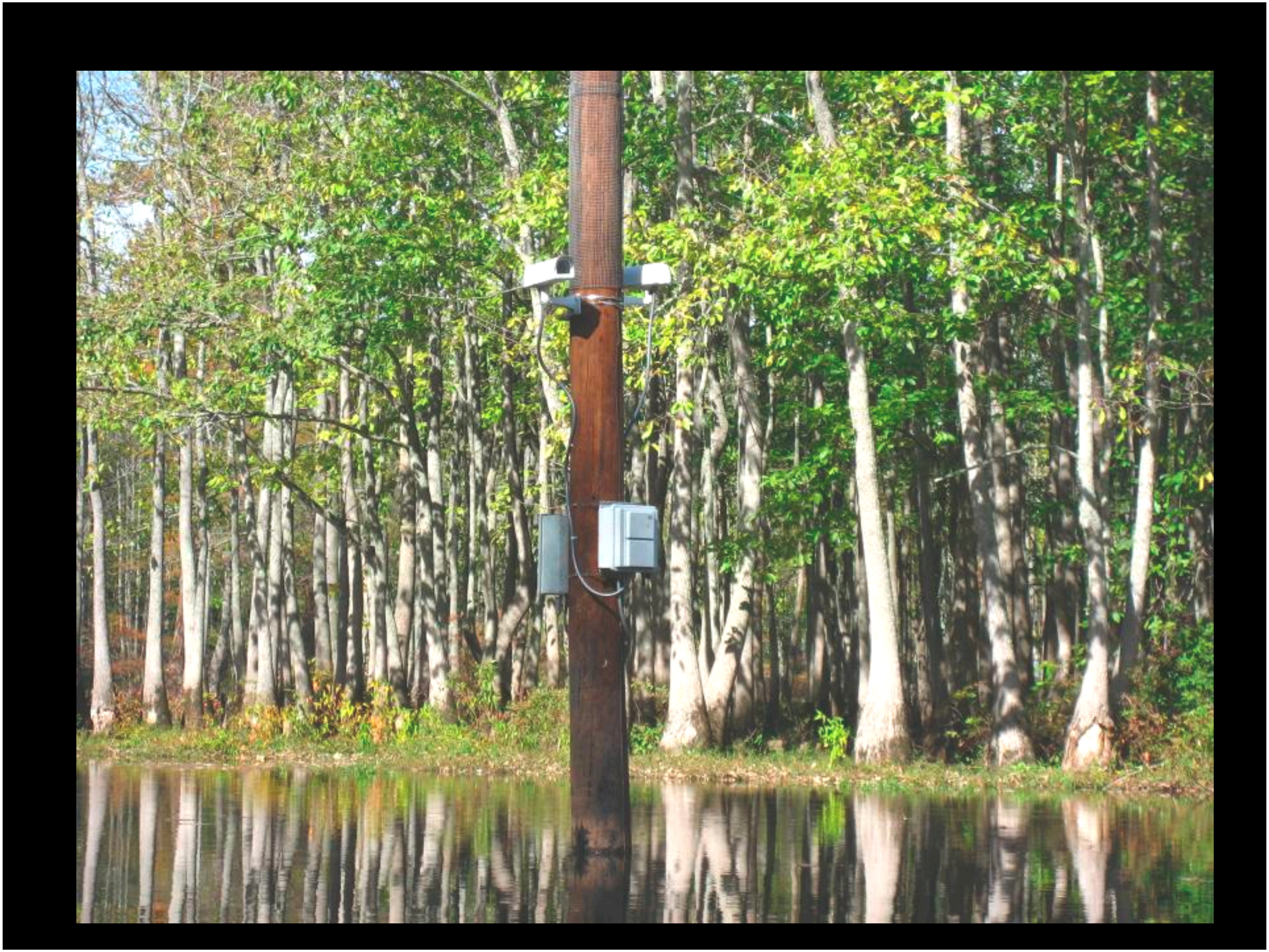
Experiments and Results

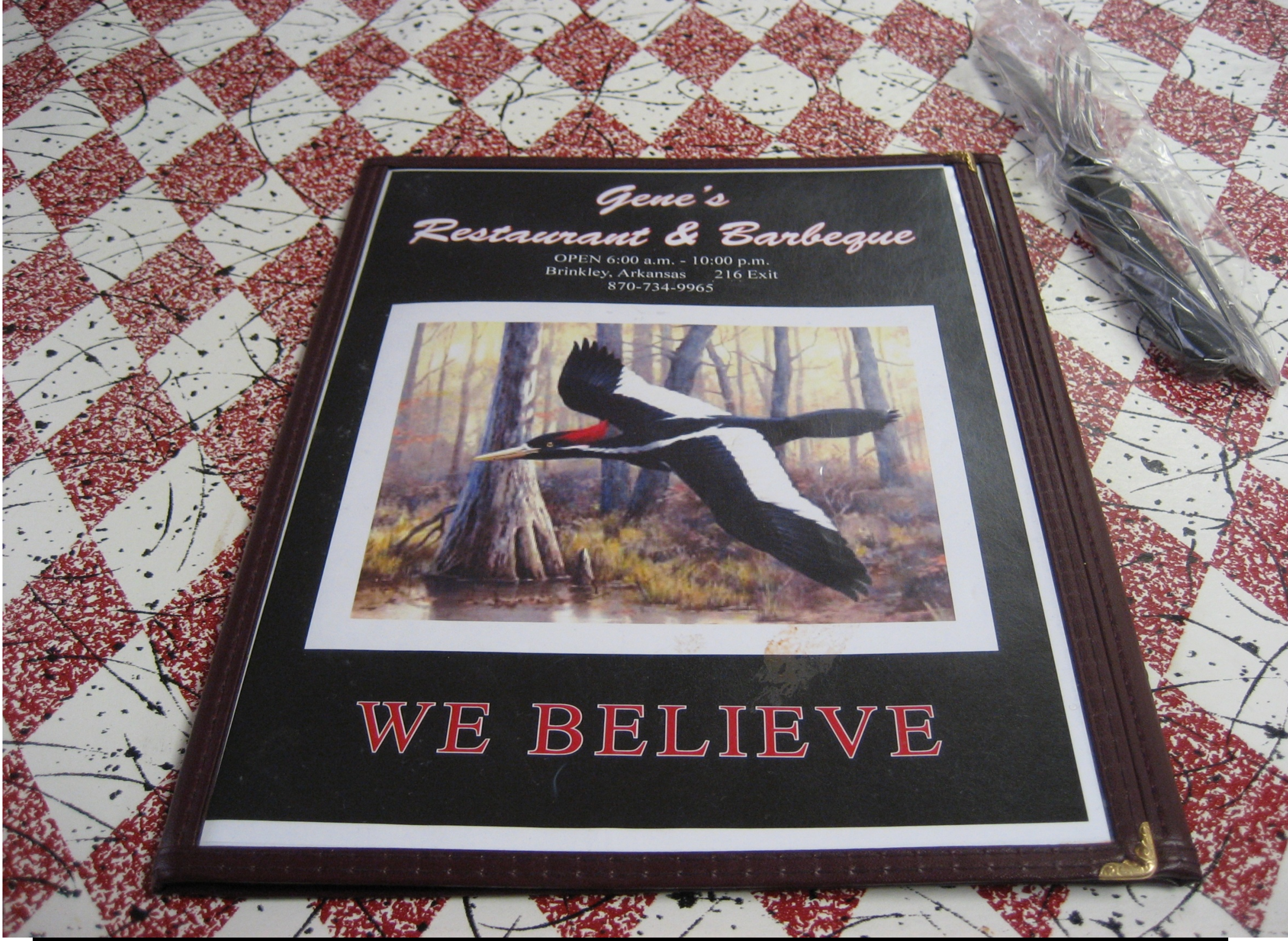
Experiments:

- Testing phase: May 2006 to Oct. 2006 in Texas A&M campus
- Field phase: Oct. 2006 to Oct. 2007 in Brinkley, AR

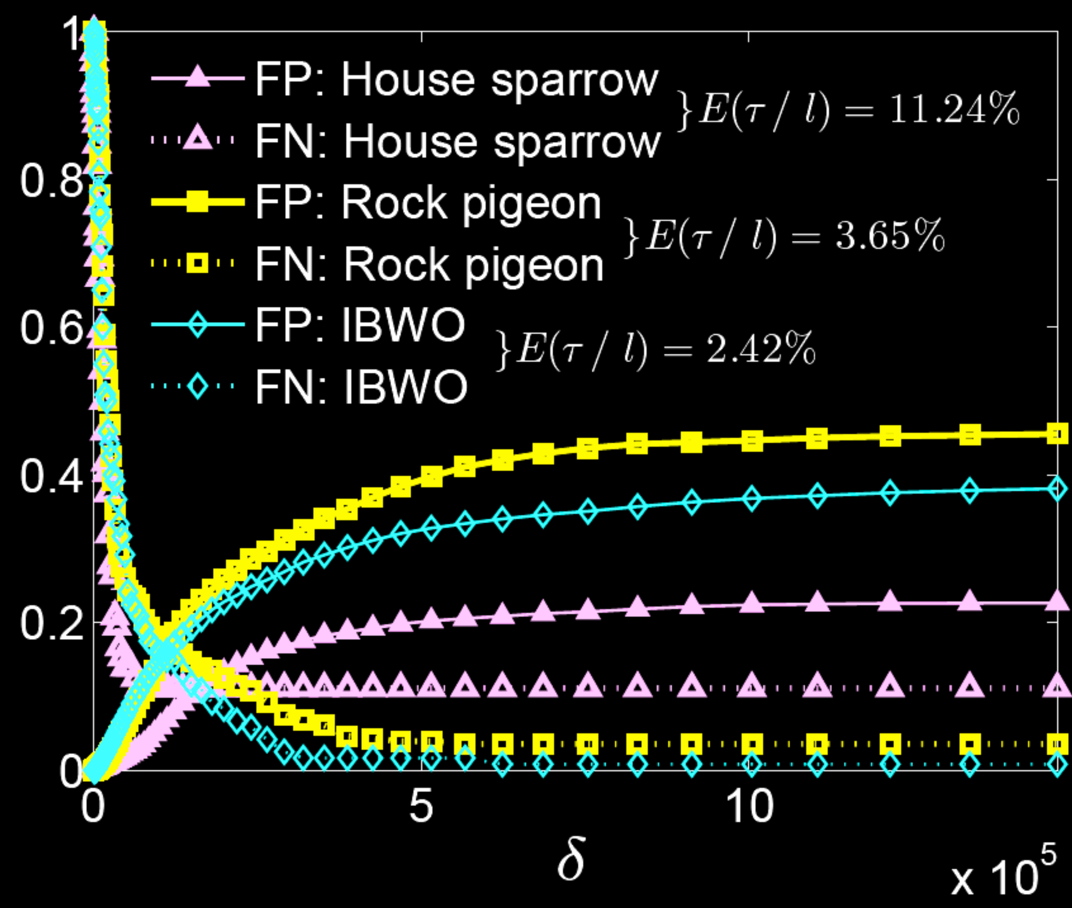






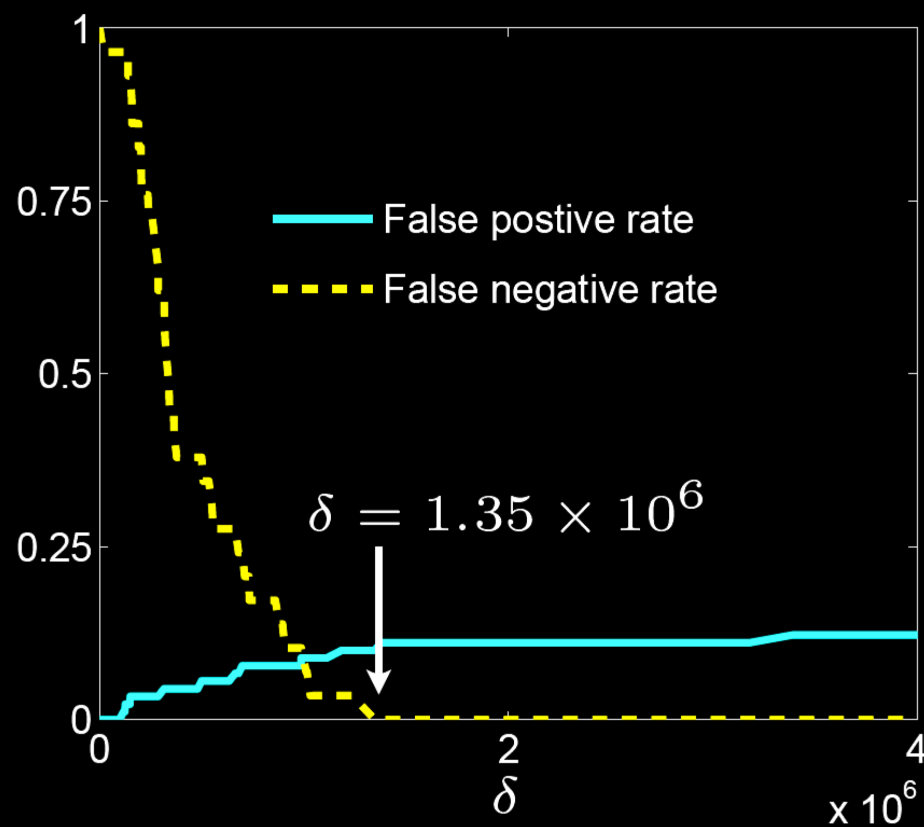

Gene's
Restaurant & Barbeque
OPEN 6:00 a.m. - 10:00 p.m.
Brinkley, Arkansas 216 Exit
870-734-9965
WE BELIEVE

Simulation on three birds



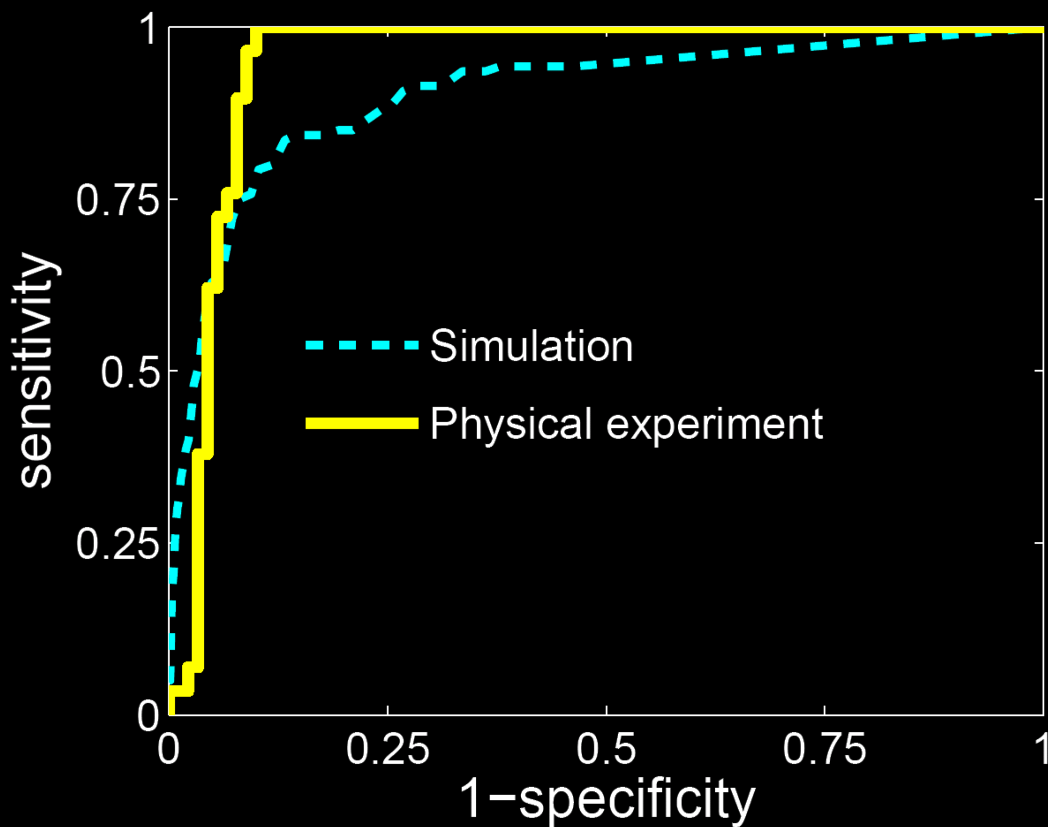
Physical Experiment on Rock Pigeon

	Pigeon	Not pigeon
Predicted pigeon	29	9
Predicted not pigeon	0	81



Insects, falling leaves, other birds, etc.

ROC Curves for Rock Pigeon



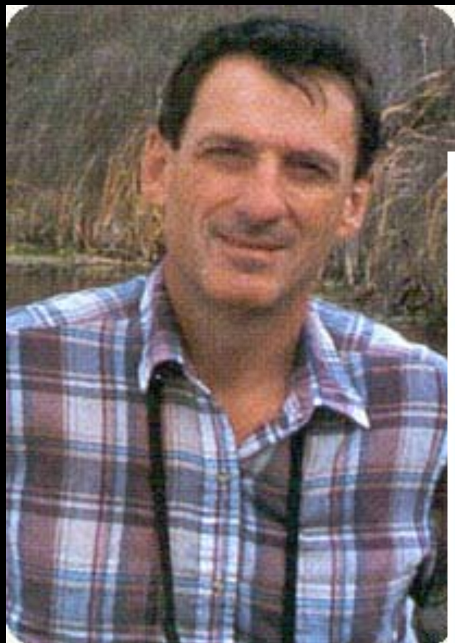
Area under ROC curve: 91.5% in Simulation; 95.0% in Experiment.

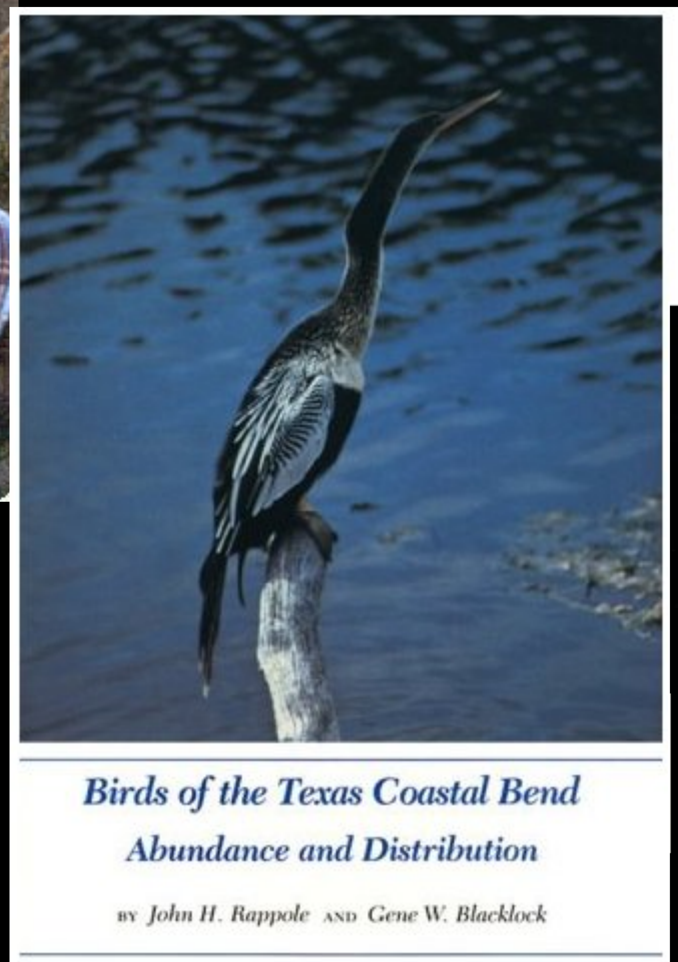

Results:

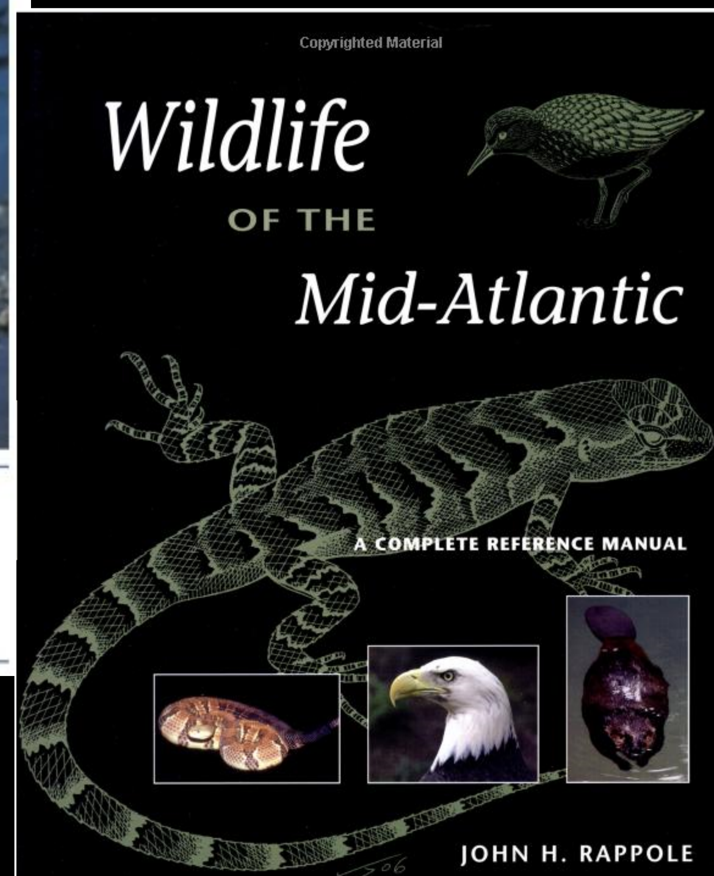
- **No Ivory-billed Woodpecker!**
- Sensitivity: <10% false negative rate
- Data reduction:
  - 146.7MB out of 29.41TB raw data
  - data reduction rate 99.9995%
- Robustness: running continuously in the Arkansas wilderness for 12 months

outline

- networked telerobots
- automated observation: ivory billed woodpecker
- engaging citizen scientists: bird range change in south texas




Birds of the Texas Coastal Bend
Abundance and Distribution
BY John H. Rappole AND Gene W. Blacklock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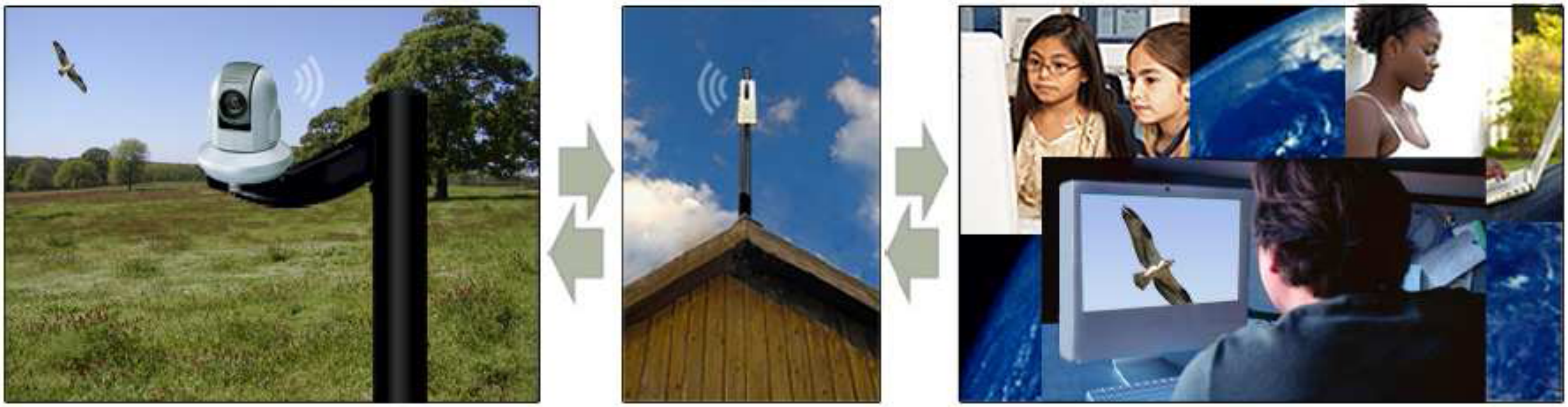
Wildlife
OF THE
Mid-Atlantic
A COMPLETE REFERENCE MANUAL
JOHN H. RAPPOLE

Project CONE-Welder

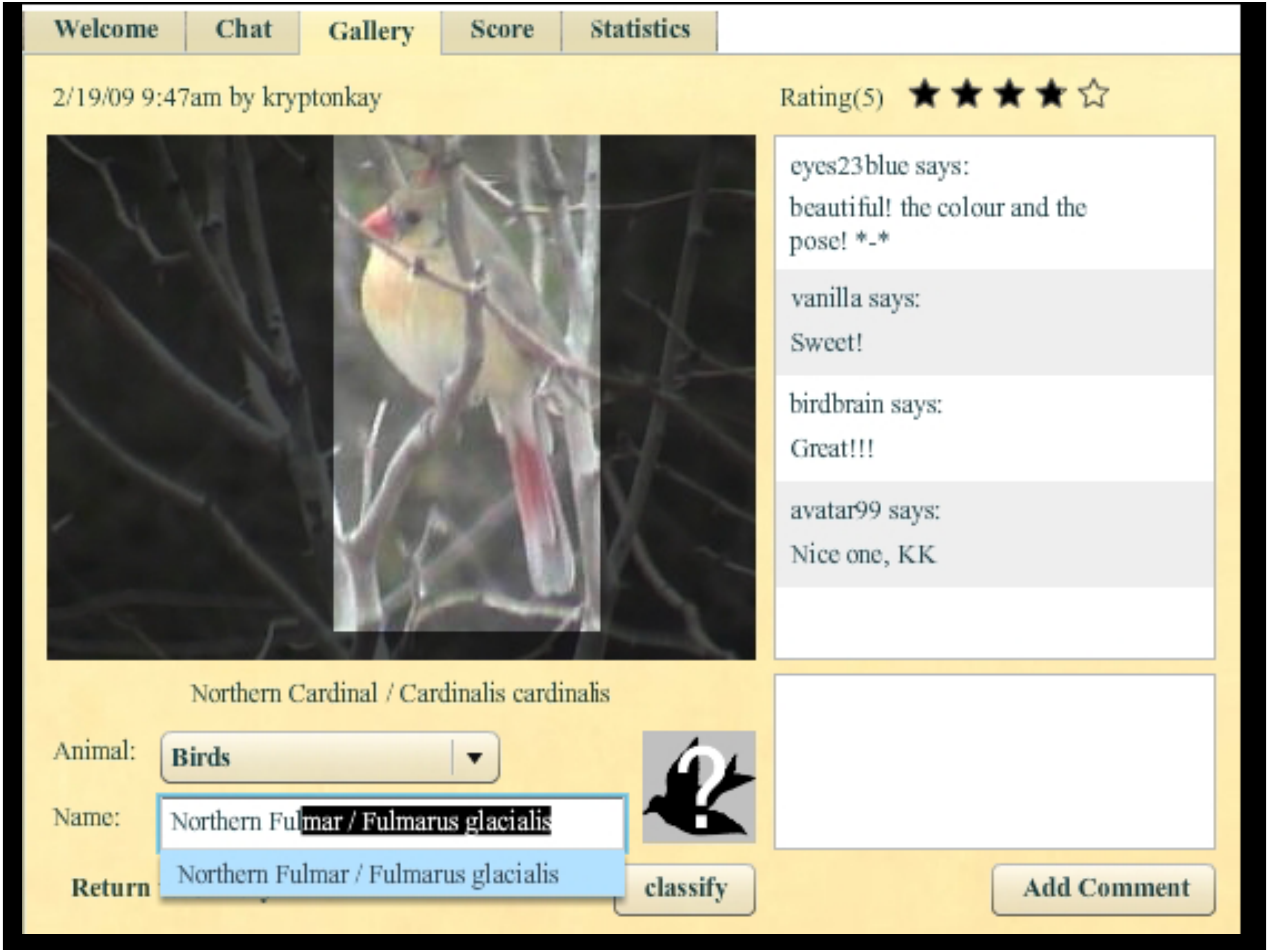


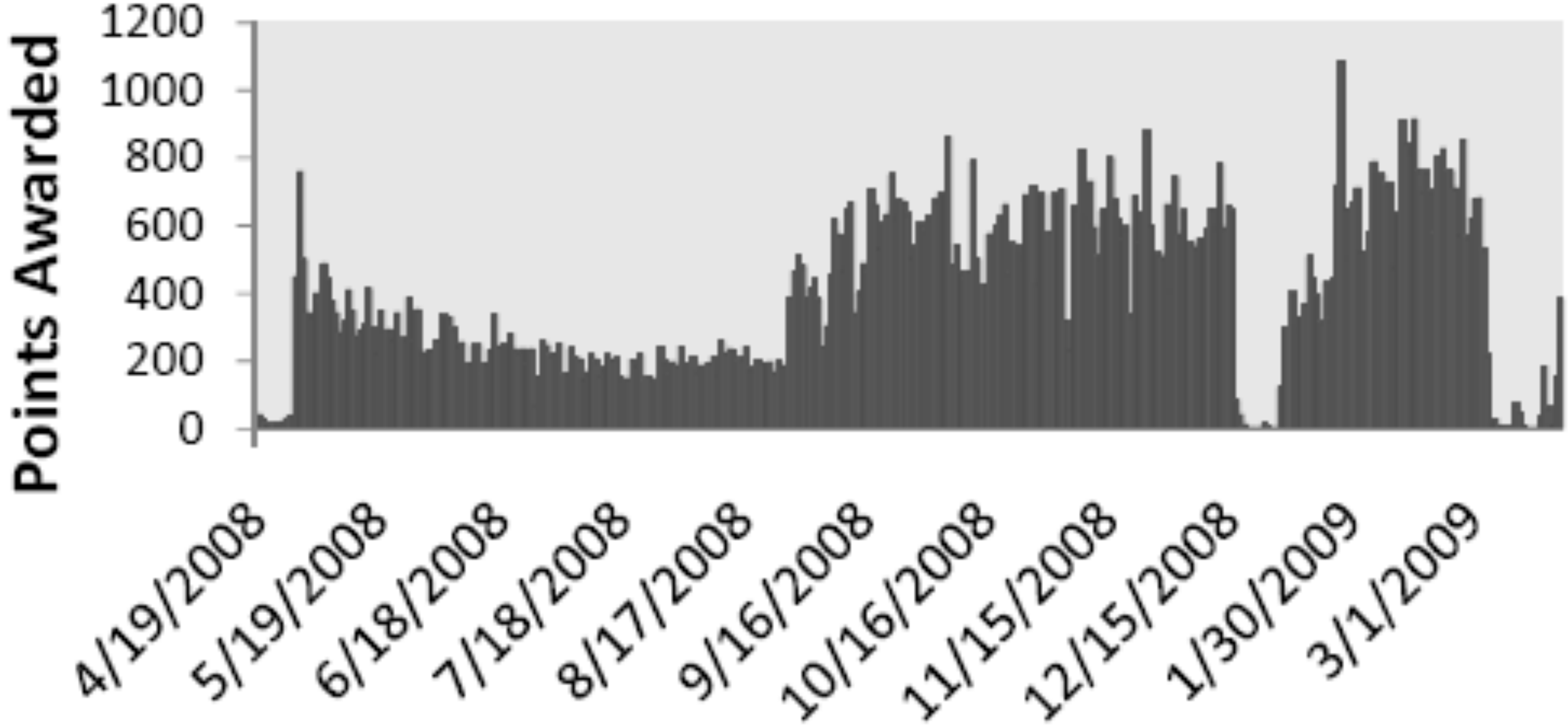
Remote natural environment with robotic camera

Relay station

Citizens from around the world participate in operating the robotic camera

Welcome
Chat
Gallery
Score
Statistics
Refresh
prev
1 / 3574
next
Show Categories
11/26/08 10:46am
txbird
#118280
11/26/08 10:28am
kryptonkay
#118267
11/26/08 10:23am
kryptonkay
#118264
11/26/08 10:22am
vanilla
#118259
11/26/08 10:22am
peteinkeyworth
#118258
11/26/08 10:22am
vanilla
#118252
zoom
CONE WELDER
COLLABORATIVE OBSERVATORIES FOR NATURAL ENVIRONMENTS
Please email support.cone.welder@gmail.com with problems/suggestions/etc.
(please note which browser version and operating system you are using)
Tutorial
FAQ
About
Blog
Search
Chat History


Welcome
Chat
Gallery
Score
Statistics
2/19/09 9:47am by kryptonkay
Rating(5)
eyes23blue says:
beautiful! the colour and the pose! *-*
vanilla says:
Sweet!
birdbrain says:
Great!!!
avatar99 says:
Nice one, KK
Northern Cardinal / Cardinalis cardinalis
Animal:
Birds
Name:
Northern Fulmar / Fulmarus glacialis
Northern Fulmar / Fulmarus glacialis
Return
classify
Add Comment


Points Awarded
1200
1000
800
600
400
200
0
4/19/2008
5/19/2008
6/18/2008
7/18/2008
8/17/2008
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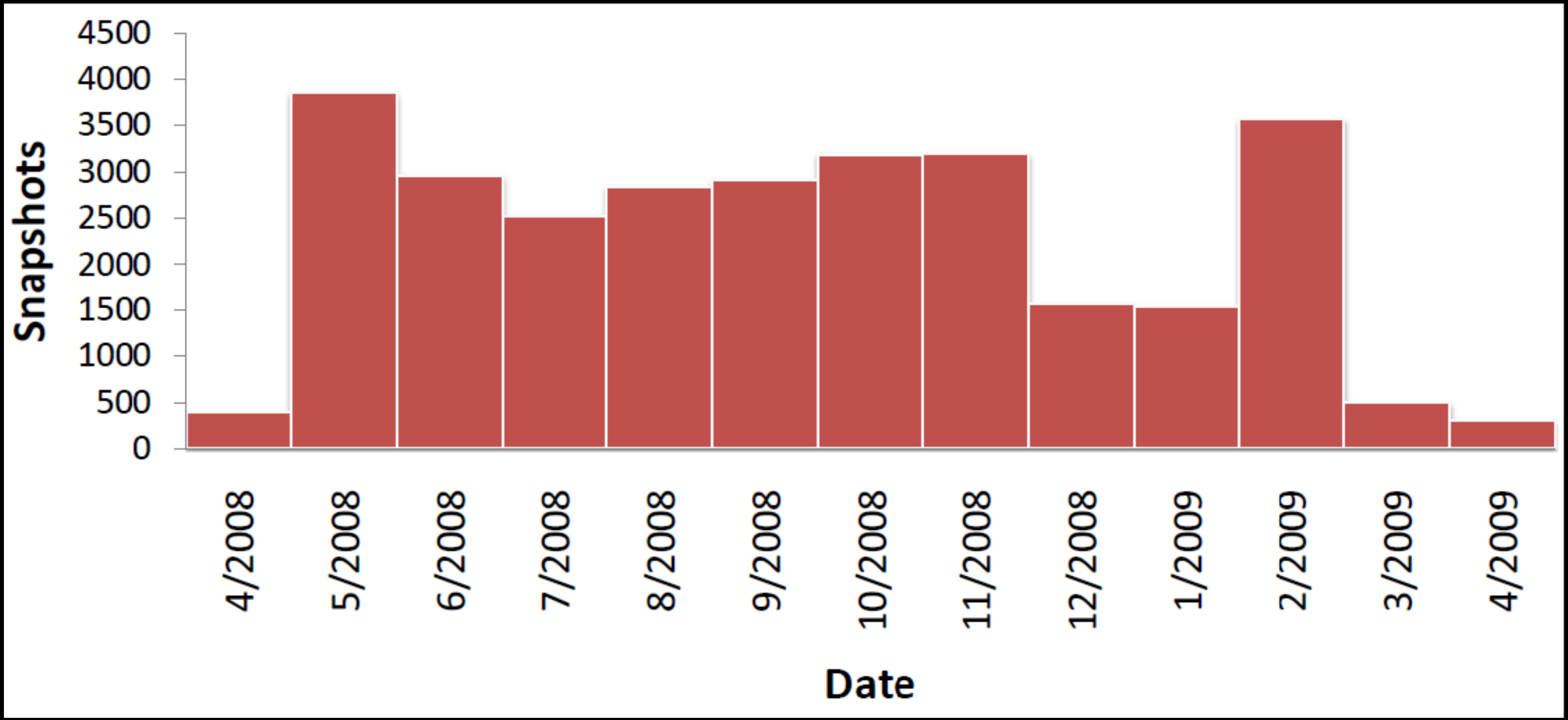
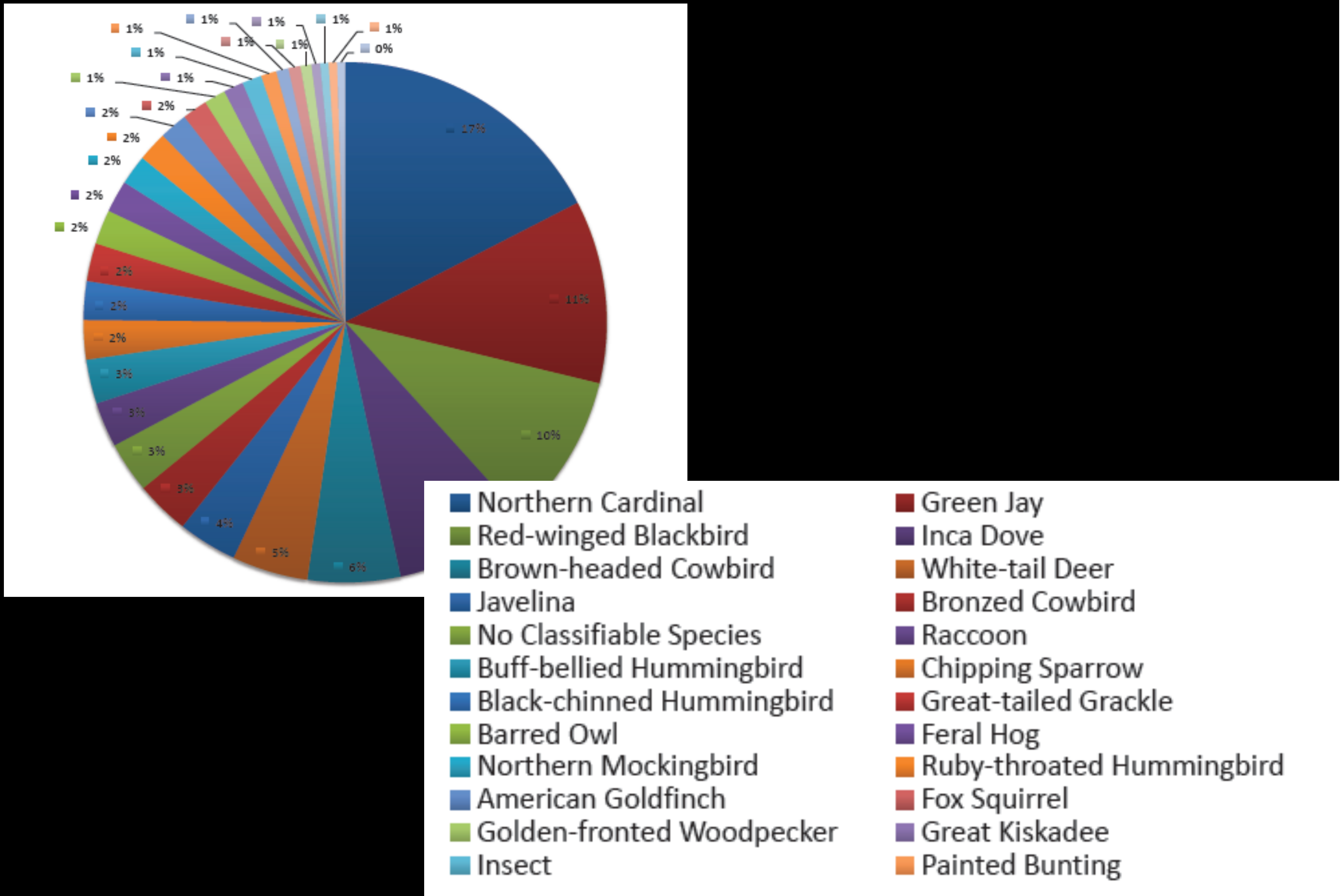
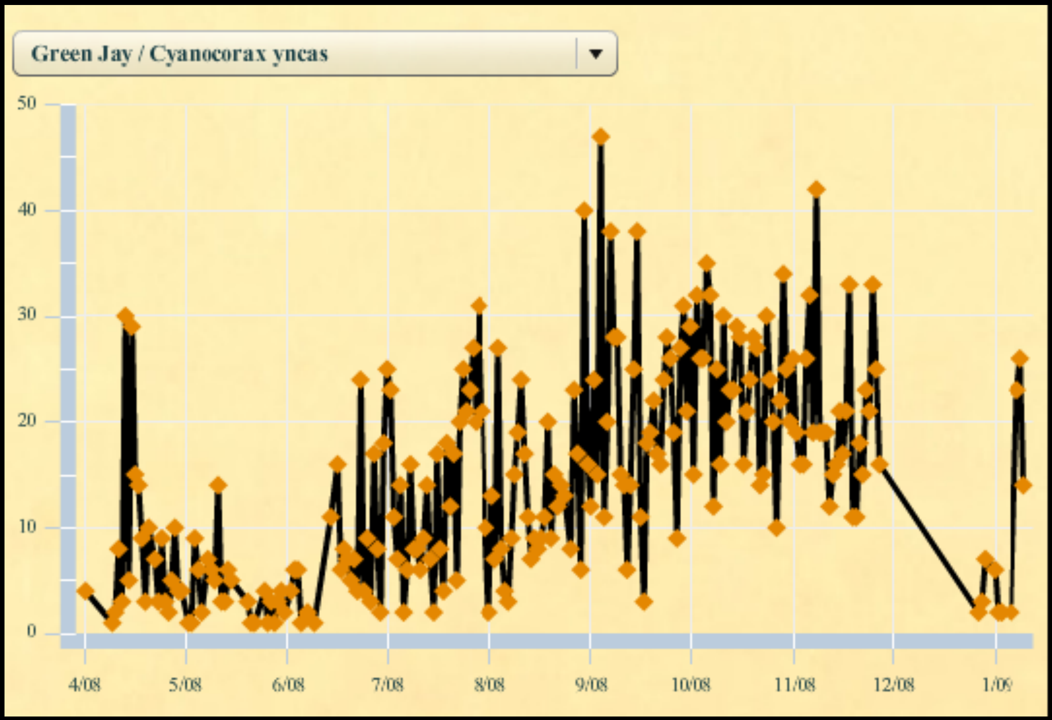
12/15/2008
1/30/2009
3/1/2009


Snapshots
4500
4000
3500
3000
2500
2000
1500
1000
500
0
4/2008
5/2008
6/2008
7/2008
8/2008
9/2008
10/2008
11/2008
12/2008
1/2009
2/2009
3/2009
4/2009
Date


Northern Cardinal
Green Jay
Red-winged Blackbird
Inca Dove
Brown-headed Cowbird
White-tail Deer
Javelina
Bronzed Cowbird
No Classifiable Species
Raccoon
Buff-bellied Hummingbird
Chipping Sparrow
Black-chinned Hummingbird
Great-tailed Grackle
Barred Owl
Feral Hog
Northern Mockingbird
Ruby-throated Hummingbird
American Goldfinch
Fox Squirrel
Golden-fronted Woodpecker
Great Kiskadee
Insect
Painted Bunting


Green Jay / Cyanocorax yncas
50
40
30
20
10
0
4/08
5/08
6/08
7/08
8/08
9/08
10/08
11/08
12/08
1/09

observed range change

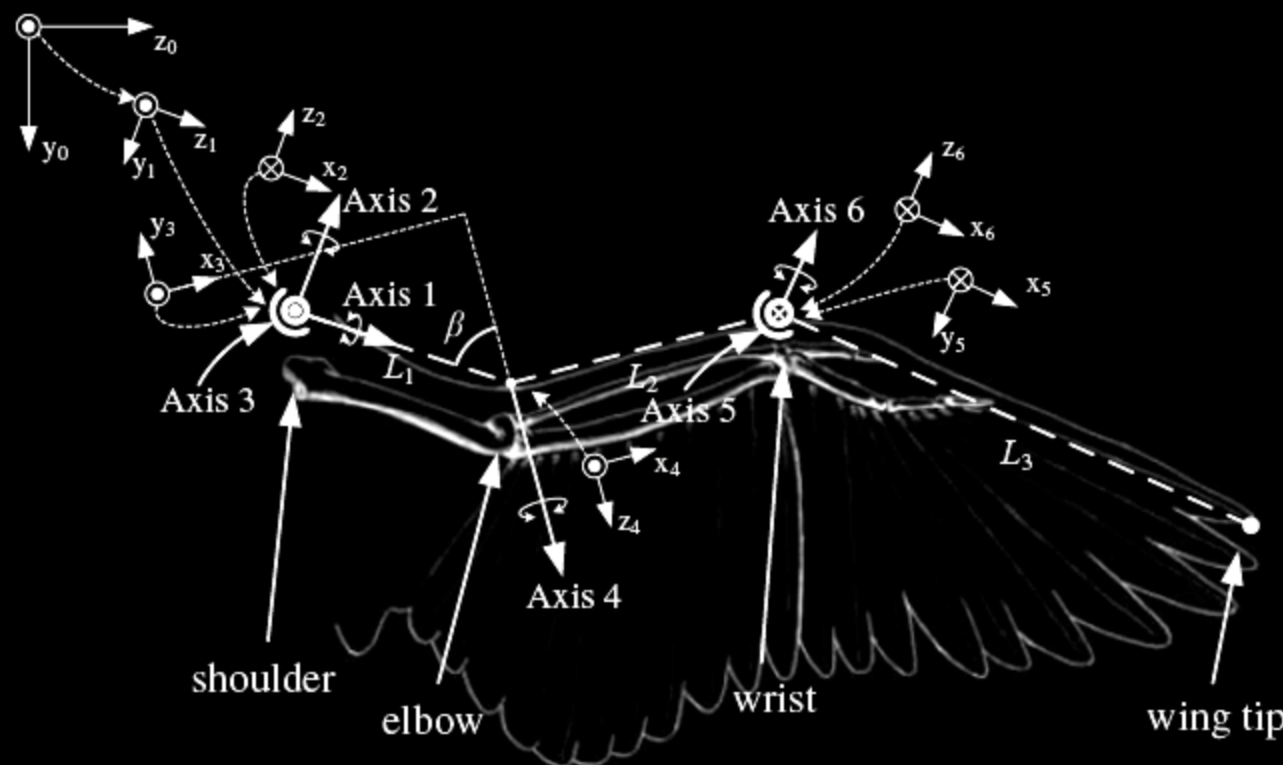
Species	Photos
Green Jay (*Cyanocorax yncas*)	3659
Bronzed Cowbird (*Molothrus aeneus*)	1710
Buff-bellied Hummingbird (*Amazilia yucatanensis*)	1671
Black-chinned Hummingbird (*Archilochus alexandri*)	768
Great Kiskadee (*Pitangus sulphuratus*)	516
Eastern Bluebird (*Sialia sialis*)	144
Audubon's Oriole (*Icterus graduacauda*)	28
Couch's Kingbird (*Tyrannus couchii*)	12

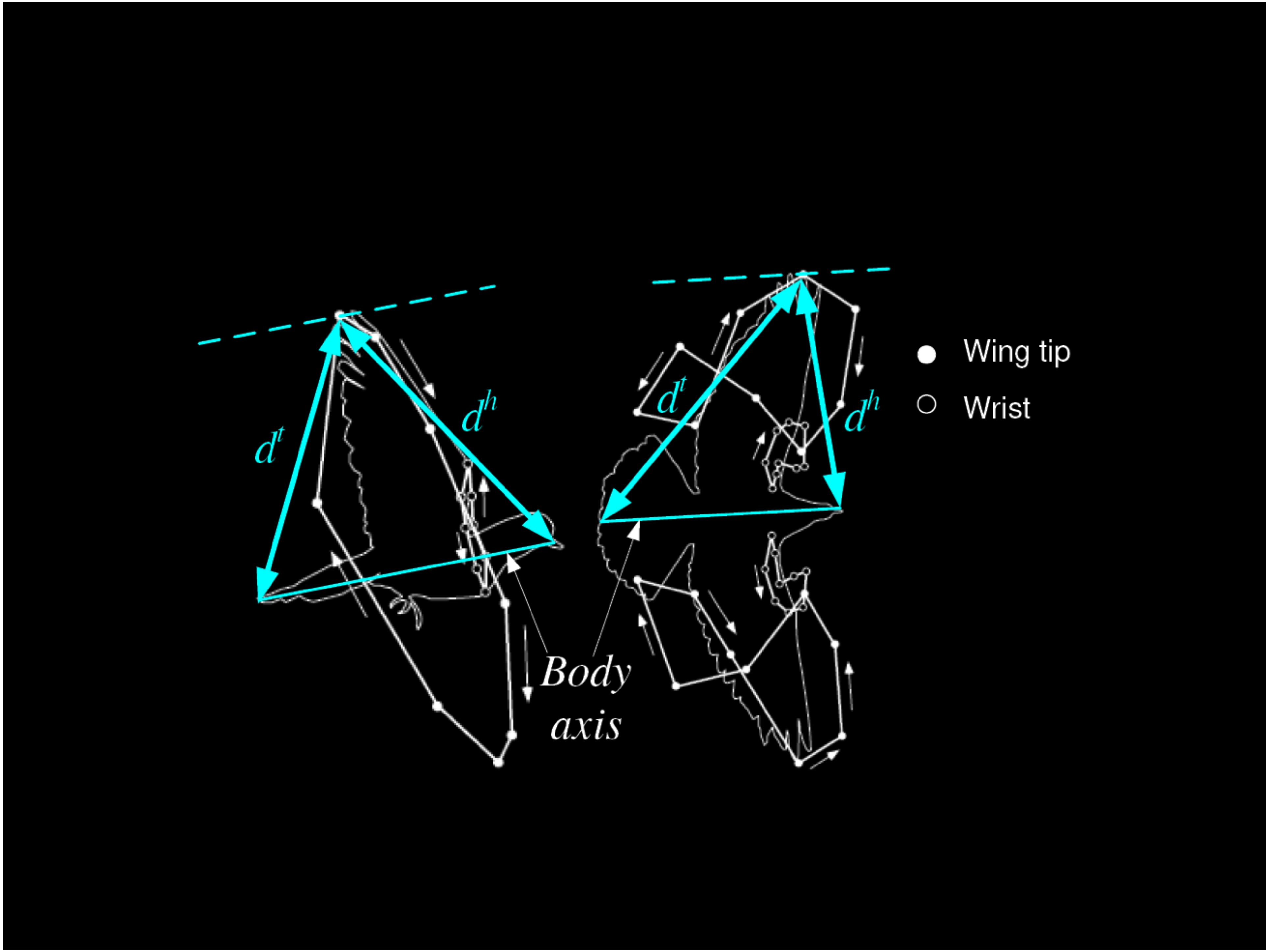
Current and Future Work

Current and Future Work

- Examine wing-flapping motion
  - Wing beat frequency is unique for each species

Wing Kinematic Model

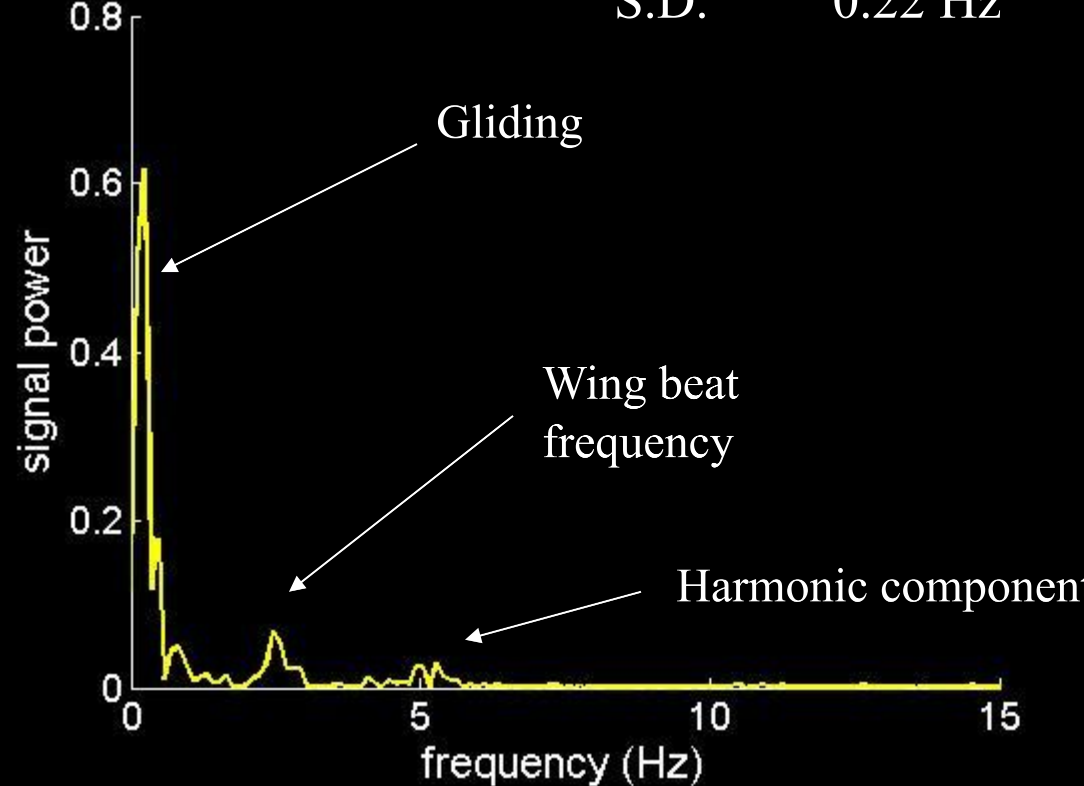


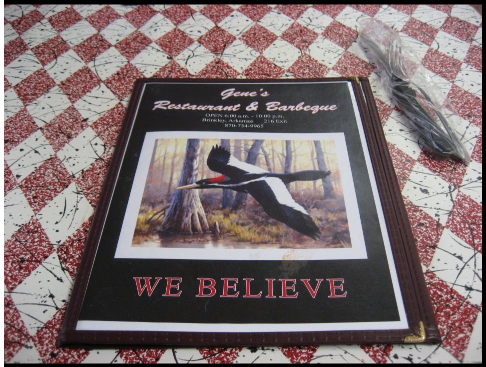


d^t
d^h
d^t
d^h
Wing tip
Wrist
Body axis

Preliminary Results

Seagull:	Mean	2.74 Hz
	S.D.	0.22 Hz





Thanks!

Websites:

http://telerobot.cs.tamu.edu

http://www.c-o-n-e.org

http://rbt.cs.tamu.edu/