Classifying Avian-Solar Interactions

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Project Overview

What's Happening?

Growth in solar energy demand

Unknown effect of solar panel infrastructure on birds

More data needed to study the effect

Argonne NATIONAL LABORATORY

Business Partner

- Science and engineering research center founded in 1940
- This project is part of the Environmental Sciences Division
- Projects including affordable clean energy and environmental protection
- Started at The University of Chicago!

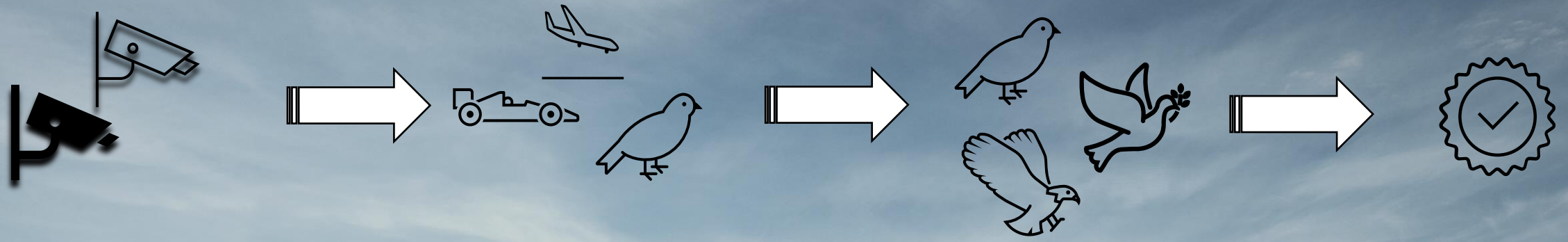
Argonne Project Stages

4K Camera Monitor

Bird Detection

Classify Bird Activity

System Implementation



Problem Statement

Current Progress

- Surveyors traverse solar fields counting dead birds
- Argonne's machine learning progress so far
  - Created a model to analyze an entire track at once and classify it as one activity
  - More than one activity can happen in a track
  - Previous model would only recognize one activity in the track below

How can we improve?

- A 2D-Convolutional neural Network that can classify single images within a track
- Assign a multilabel to the track based on the labels of each frame
- New model Identifies both activities in the track below

Financial and Global Impact

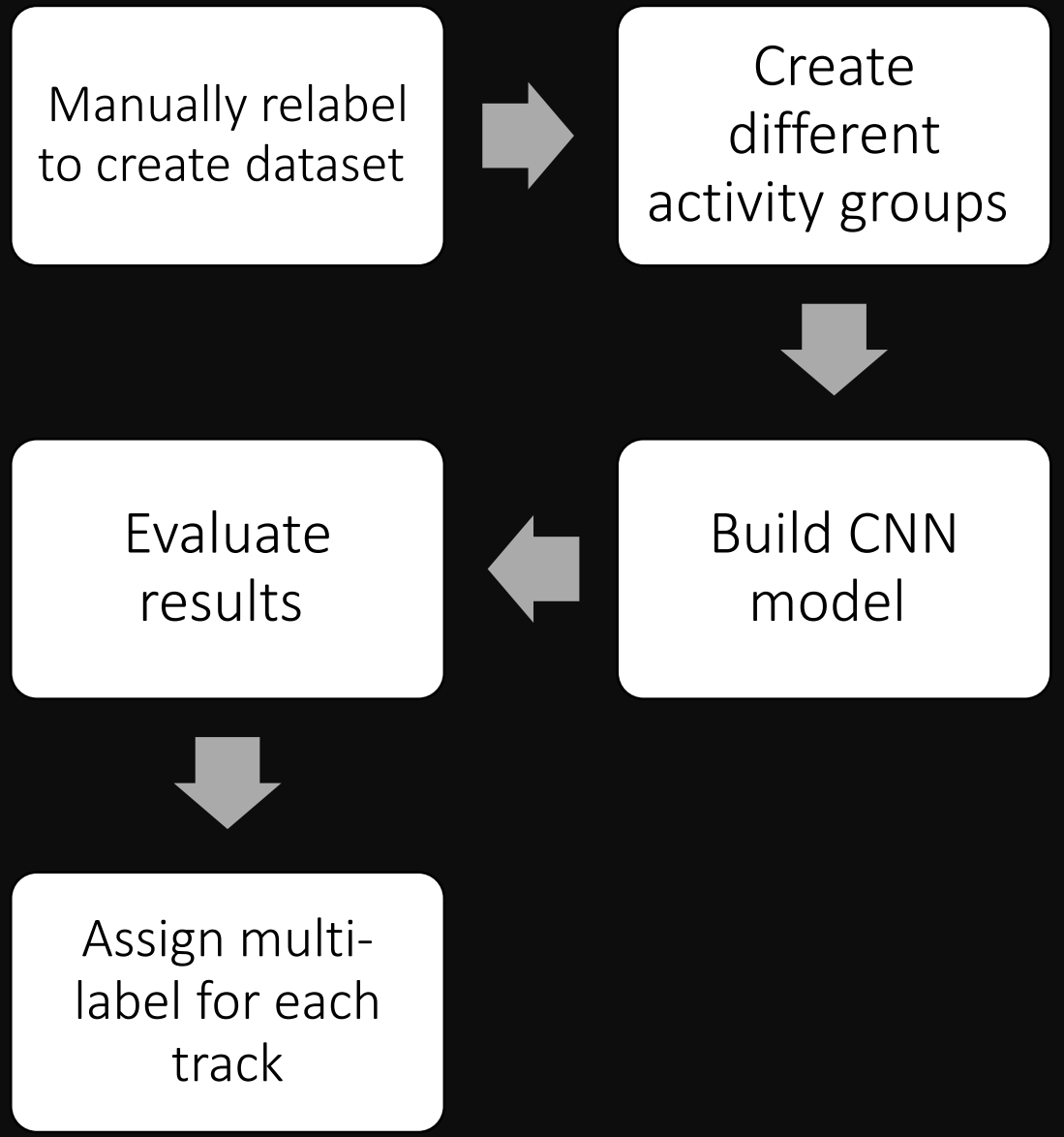
- Less surveyors needed to walk the sites
- Saving 50k/year per 100 acres
- Scalable and reliable data

How can this model be used?

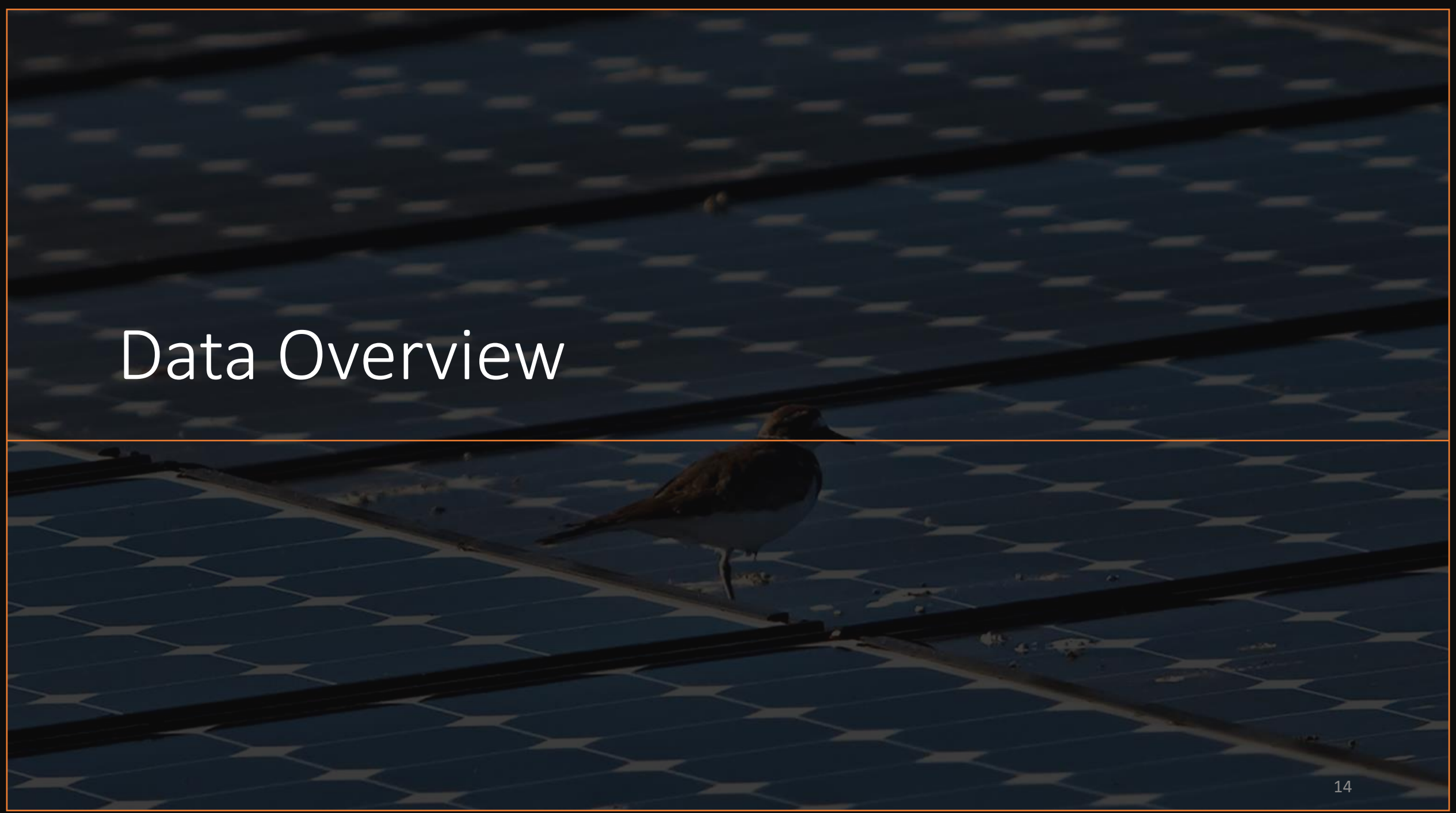
- Intended to generalize to sites across the United States
- Geographically diverse sites included in the training dataset
- Limitations
  - Each site has a unique man-made landscape
  - Noisy backgrounds may hinder predictive power

Analysis Plan

Goal of Analysis



Data Overview



Data we received from Argonne

	Directory	Label	x	y	speed	area	obj_id	frame	image_count
0	/project2/msca/projects/AvianSolar/ImageDatase...	Flying with solar panel	832	1134	66.79106	12769	40273	2184	28.0
1	/project2/msca/projects/AvianSolar/ImageDatase...	Flying with solar panel	1692	1330	89.06198	13447	40273	2196	28.0
2	/project2/msca/projects/AvianSolar/ImageDatase...	Flying under solar panel	2988	1787	147.78356	13340	40273	2207	28.0
3	/project2/msca/projects/AvianSolar/ImageDatase...	Flying over reflection	1598	1310	84.22580	13221	40273	2195	28.0
4	/project2/msca/projects/AvianSolar/ImageDatase...	Flying under solar panel	3149	1856	161.16776	12656	40273	2208	28.0

Directory Path

Single Activity Label per Track

Metadata

Metadata associated with each track

- generated using Argonne's existing tracking algorithm
- Track & Image ID
- Bird’s x-position in the 2D frame
- Bird's y-position in the 2D frame
- Bird’s speed
- Bird’s size
- Served as numeric input for this classification problem
- Standardized before model training

Track ID	Image ID	X	Y	Speed	Area
1	1	3600	489	20.87	12430
1	2	3581	486	20.86	12430
1	3	3545	484	20.84	12210
...	...	...	...	...	...

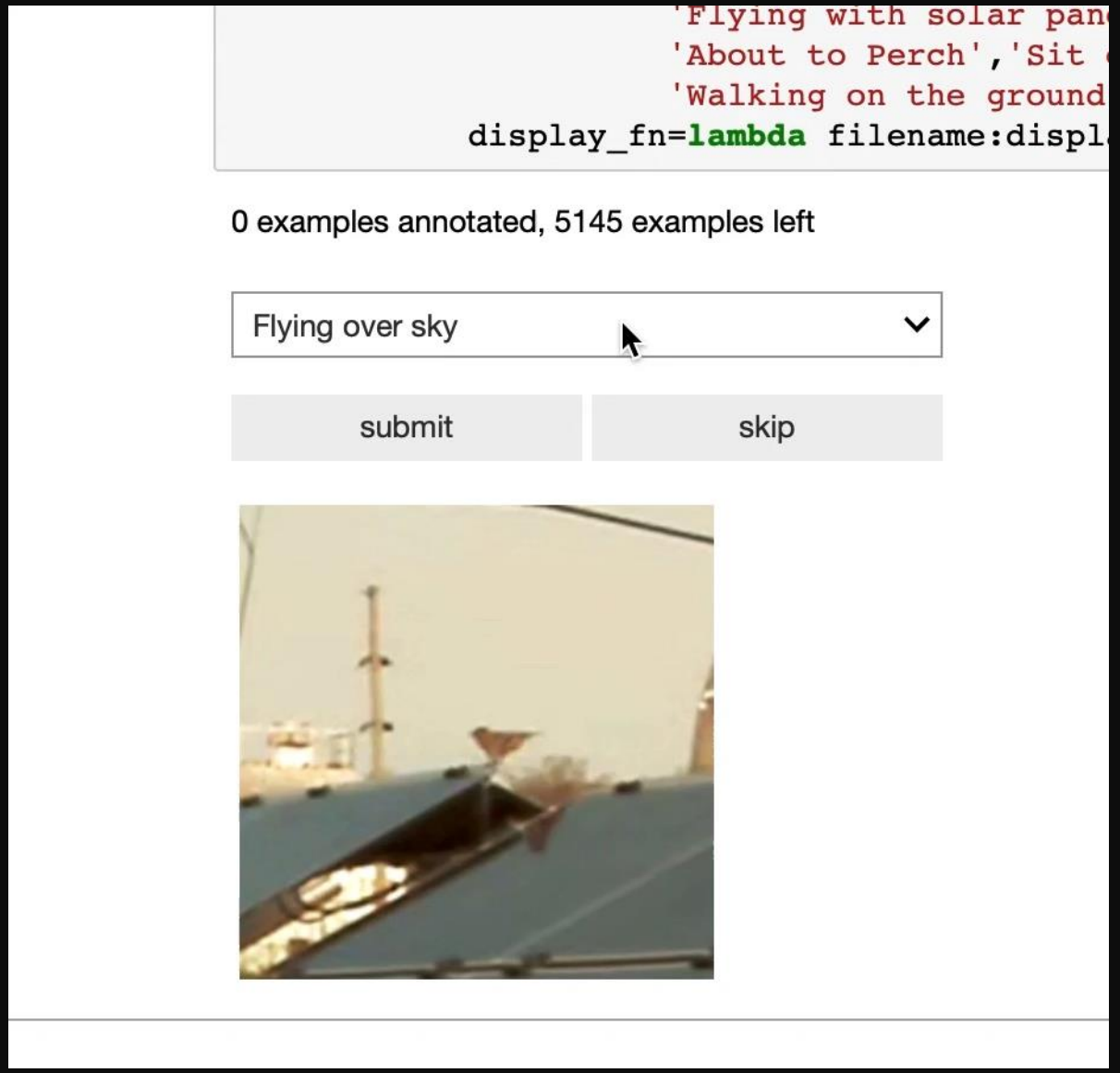
Labeling Method

Previous Argonne Projects

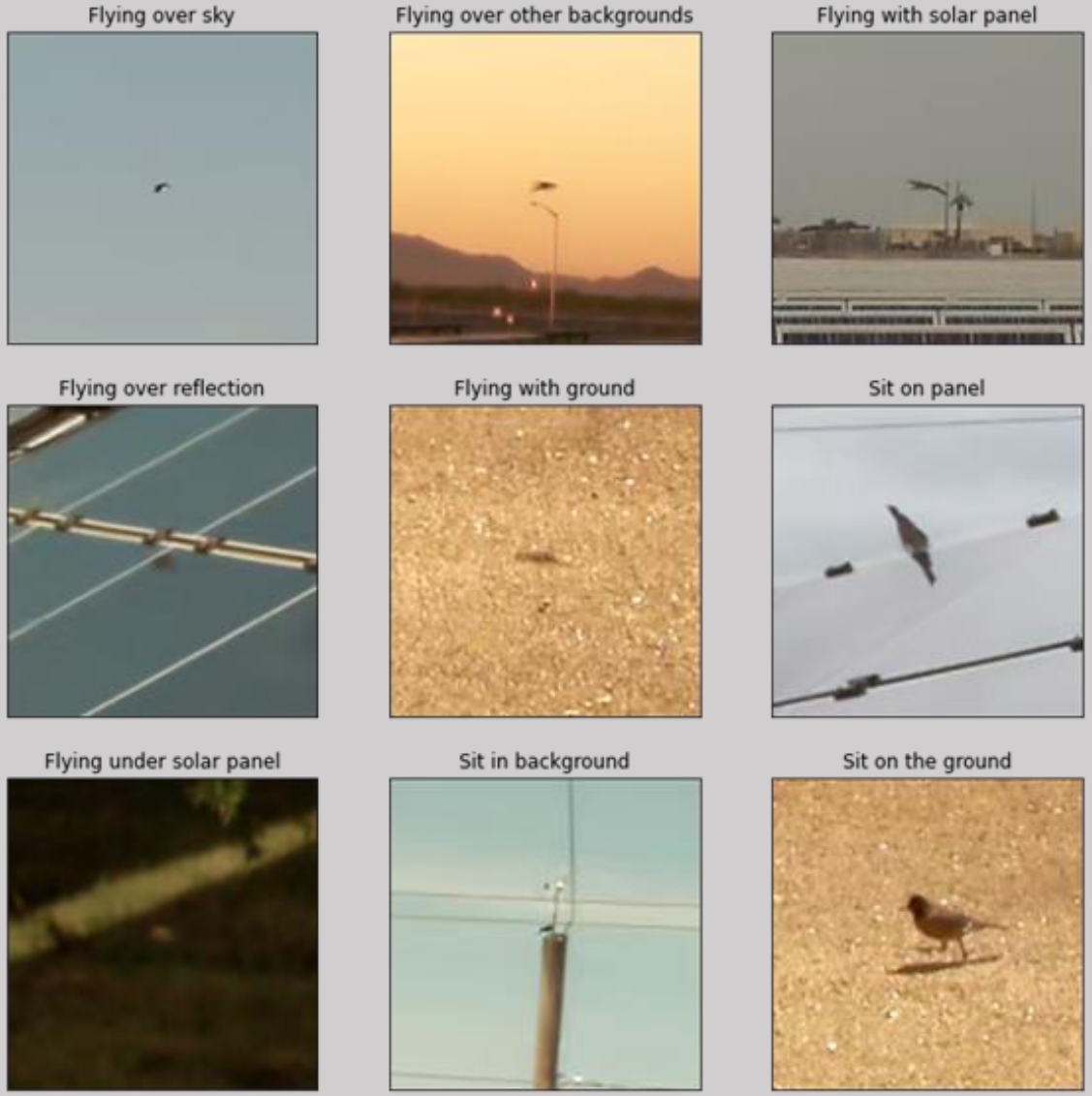
- Unit of analysis was entire track

Our Project

- Unit of analysis are the frames of the track
- This dataset did not exist, so we had to create it
- Manually labeled 74,011 frames



Created 9 activity lables to describe bird behavior



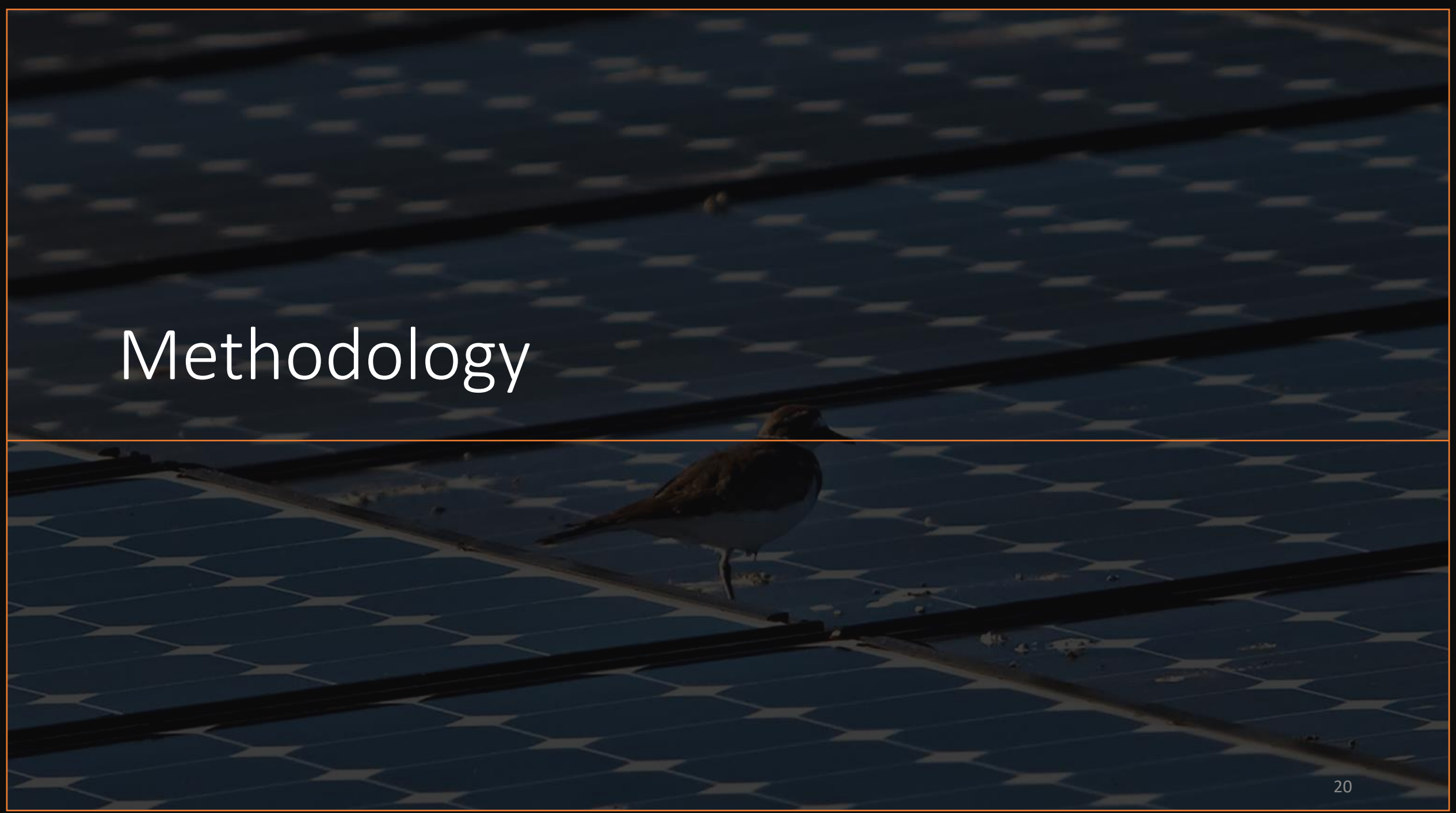
- Image shape: 200 x 200 x 3 (RGB)
- Pixel value: 0 to 255
- 9 activity labels
  - Flying over sky
  - Flying over other backgrounds
  - Flying with solar panel
  - Flying over reflection
  - Flying with ground
  - Sit on panel
  - Flying under solar panel
  - Sit in background
  - Sit on the ground

Distribution of bird activity labels

- Highly imbalanced
- "Flying over sky" 46% of cases
- Top 4: 88% of entire dataset

Label	Count	Percentage
Fly over sky	34080	46.05%
Fly over other background	12382	16.73%
Fly with solar panel	10449	14.12%
Fly over reflection	9538	12.89%
Fly with ground	2541	3.43%
Sit on panel	2203	2.98%
Fly under solar panel	1389	1.88%
Sit in background	1039	1.40%
Sit on ground	390	0.53%

Methodology



Label Groupings

Merge similar activity labels along with under-sampling to reduce imbalances

Group 1

- Flying
- Not Flying

Group 2

- With Panel
- Without Panel

Group 3

- Background
- Panel
- Ground

Group 4

- Background
- Fly with panel
- Interact with panel
- Ground

Full Label

- Full label with 9 categories

Train - Test – Validation Split

Split by track

- Entire track assigned to either train, test, or validation
- Higher generalizing power
- Randomly assigning images creates data leakage
  - A track can contain nearly identical images

Example: Entire track below is placed in training set

Data Pipeline

Dataset

Path	Metadata	Label

CSV File

Preprocessing

- Label encode
- one-hot encode
- standardize meta data

tf.data

Extract

Image

Metadata

Label

Transform

Decode images into pixel

Resize to (224x224x3)

resnet50.preprocess_input

tensor

tf.float32

tensor

tf.float32

tensor

tf.int32

zip

Optimize

- Cache
- Batch
- Prefetch

Load

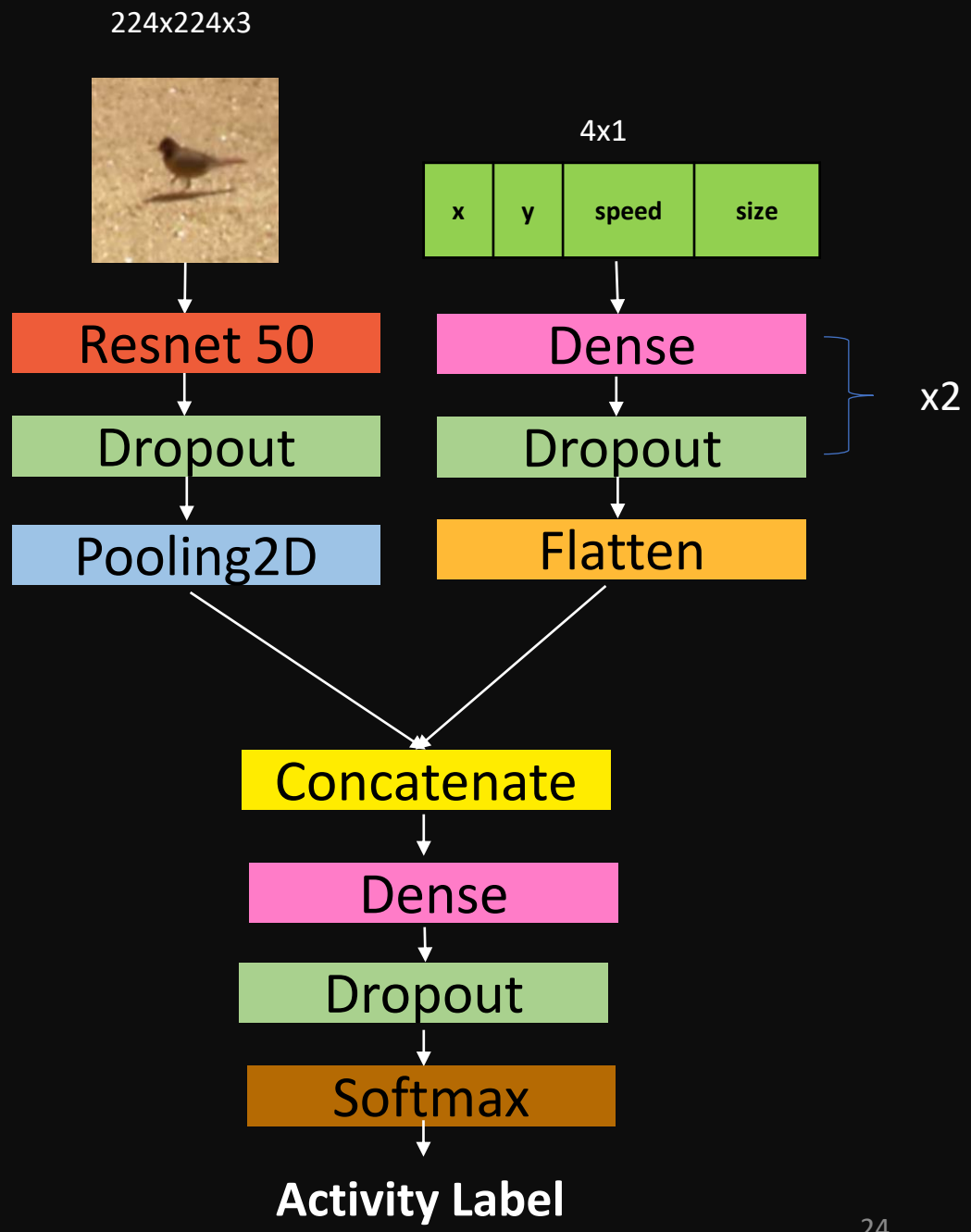
(None,224,224,3)

(None,4)

(None,3)

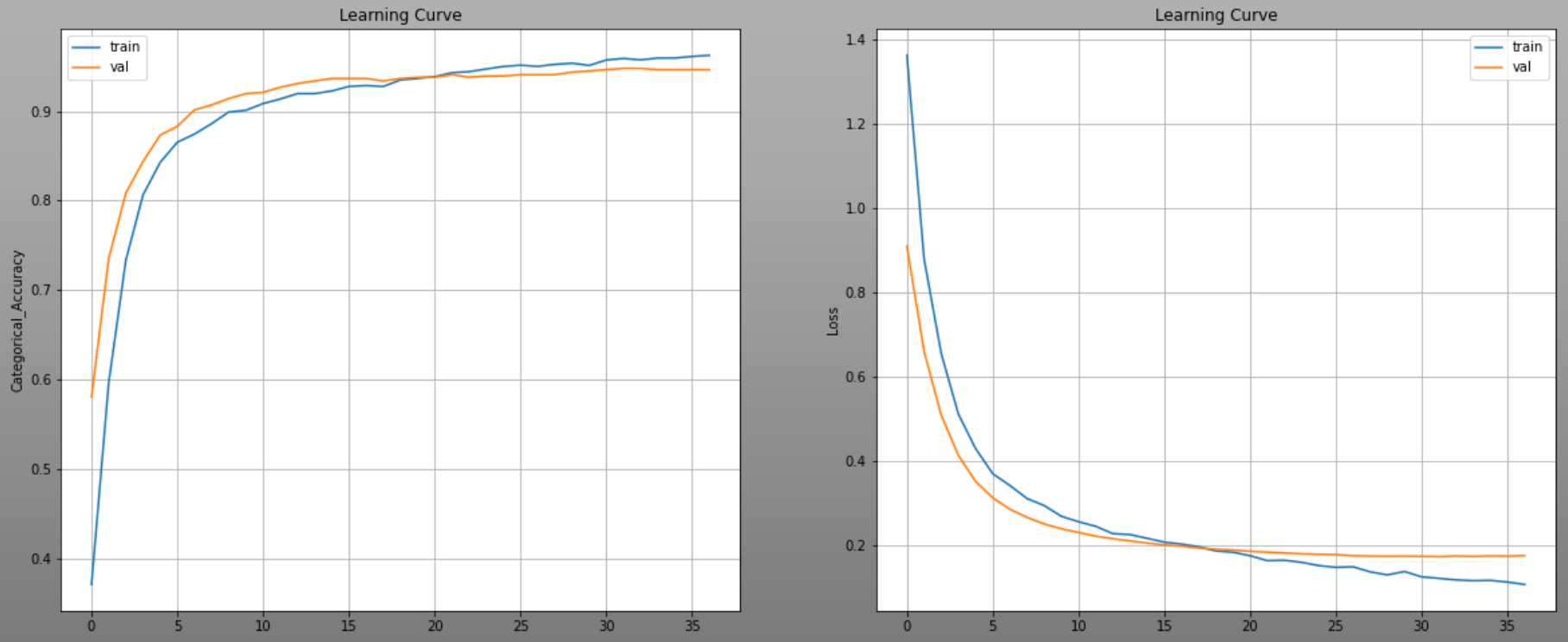
Model Framework

- Inputs: Image (224,224,3) and Metadata (4,1)
  - Tensor object: Prefetch Dataset
- Outputs: Activity Label
- Resnet 50 to train image data
  - 48 Convolutional layers
- Dropout layers to prevent overfitting
- Two branches are concatenated
- Followed by fully-connected layer



Model Evaluation and Validation

- Categorical Accuracy
- Categorical Loss Entropy
- Callback (Monitor on Validation loss)
  - Checkpoint
  - Early Stopping



Learning curves for group 3

Findings and Discussions

Model Performance Metrics – Full Dataset

Group 1
- Flying
- Not Flying

Group 2
- With Panel
- Without Panel

Group 3
- Background
- Panel
- Ground

Group 4
- Background
- Fly with panel
- Interact with panel
- Ground

Full Label
- Full label with 9 categories

	Accuracy	Precision –MA	Precision –WA	Recall – MA	Recall – WA	F1 – MA	F1 –WA
Full Label	0.75	0.63	0.83	0.69	0.75	0.58	0.77
Group 1	0.85	0.62	0.96	0.89	0.85	0.64	0.89
Group 2	0.89	0.87	0.92	0.92	0.89	0.88	0.89
Group 3	0.94	0.82	0.95	0.95	0.94	0.87	0.94
Group 4	0.87	0.71	0.92	0.85	0.87	0.74	0.88

Group 1 : Flying

Group 1 : Non-Flying

- Model relies mainly on recognizing the background rather than birds' activity in the image
- Images with similar backgrounds exist for both labels in Group 1
- Group 2 has background-based label (panel vs. no panel), and thus performs better than Group 1

Final Model Output

- Actual model predictions for a track
- Model correctly captures both activities
  - Flying over sky
  - Flying with solar panel

Model Limitations and Future Work

- Model Limitations:
  - Lack of appropriate under-sampling or over-sampling method to transform the images together with the metadata by the same degree
  - The model cannot incorporate edge cases like collision due to scarcity in the training dataset
- Future Works:
  - Manually label more data to increase amount of training data
  - Utilize Active Learning to predict unlabeled images
  - Image augmentation


Thank you!