

# Image Classification with CIFAR-10

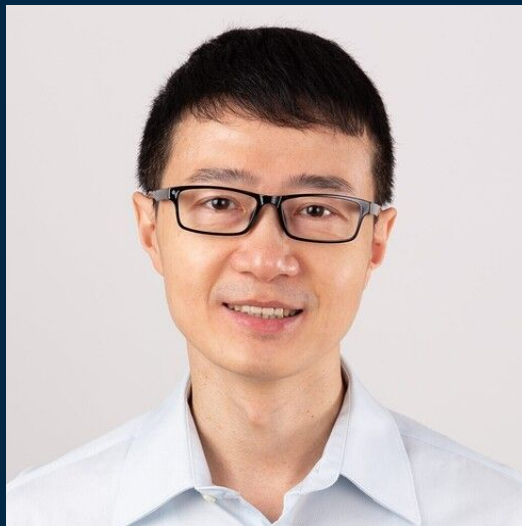
April 2023

**Presenters:** Snithika Reddy, Hsi-sheng Wei, Andrew Abrahamian

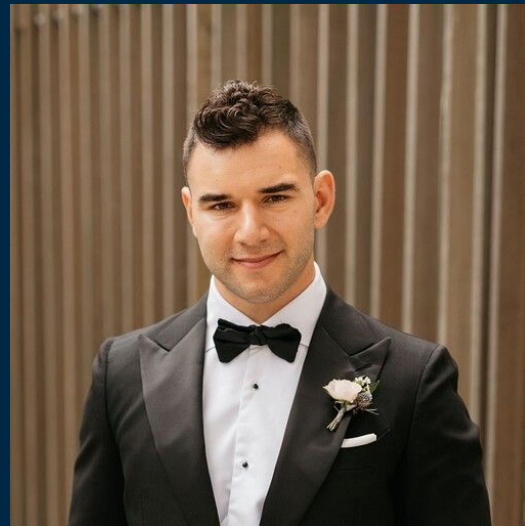
# Meet Our Team



Snithika Kalakoti  
Data Scientist



Hsi-sheng Wei  
Data Scientist



Andrew Abrahamian  
Data Scientist

# Agenda

Framing the Objective: The What, How, and Why?

Modeling Approach & Experiments

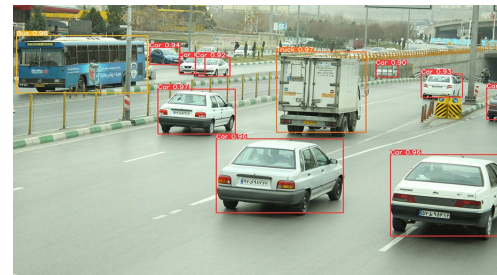
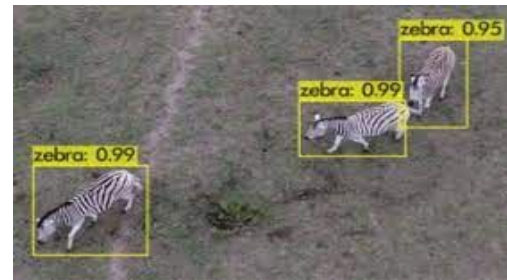
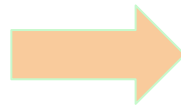
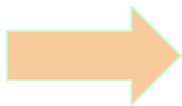
Results & Conclusions

Ethical Considerations & Limitations

Q&A

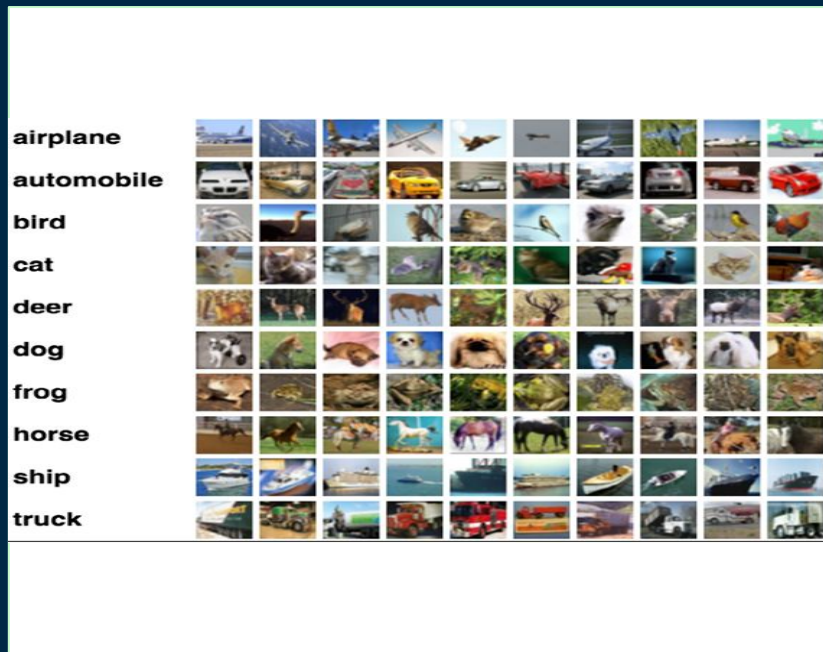
# What, How, and Why?:

Startup that builds machine learning models to classify images



# Our Data & Solution Approach

## CIFAR-10 Dataset



## FNN Confusion Matrix

True Label	airplane	452	43	117	19	37	5	50	19	192	66
	automobile	16	634	30	16	12	2	27	18	85	160
	bird	63	24	427	80	117	35	154	43	37	20
	cat	15	23	138	336	73	66	213	41	36	59
	deer	28	14	208	49	396	13	172	59	39	22
	dog	6	22	179	233	67	233	136	54	41	29
	frog	2	9	97	55	68	21	696	18	15	19
	horse	17	17	131	84	106	25	56	491	21	52
	ship	72	65	23	24	21	4	23	15	687	66
	truck	23	184	30	32	8	7	41	36	60	579
			airplane	automobile	bird	cat	deer	dog	frog	horse	ship
Predicted Label											

- CIFAR-10: 60k 32x32 images (50k training, 10k testing): ideal for our use case
- Starter FNN model did not perform well (49% test accuracy); animal precision was a problem

# Building Deeper CNN Models

**CNN1** (70% test accuracy)

True Label	airplane	765	32	66	18	10	3	8	11	56	31
	automobile	17	873	3	9	1	0	5	2	16	74
	bird	61	14	679	55	36	53	50	27	13	12
	cat	22	27	106	492	56	135	63	48	18	33
	deer	30	8	126	76	570	30	61	77	11	11
	dog	15	14	100	195	34	525	25	67	9	16
	frog	8	19	64	55	24	22	763	14	13	18
	horse	18	4	60	31	43	42	11	766	2	23
	ship	71	38	16	10	2	4	1	4	826	28
	truck	33	116	11	11	1	5	3	11	31	778
Predicted Label											
airplane automobile bird cat deer dog frog horse ship truck											

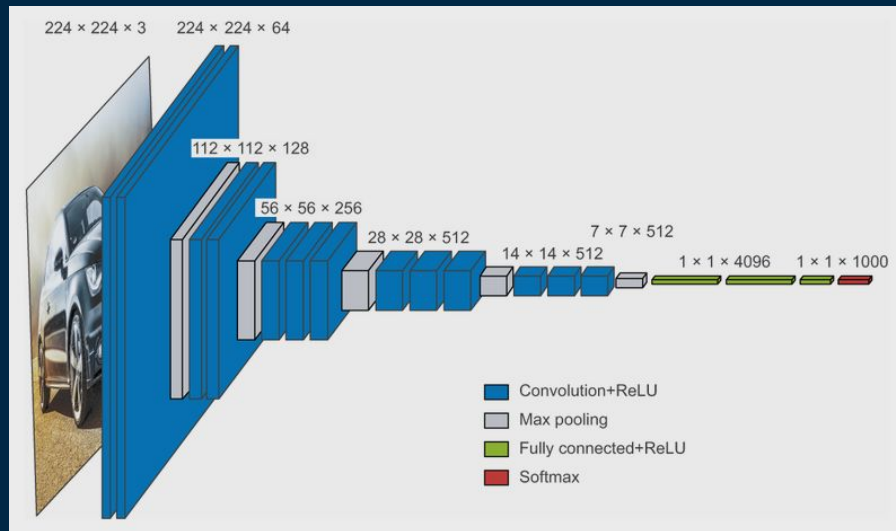
**CNN3** (83% test accuracy)

True Label	airplane	783	5	88	27	16	8	9	7	46	11
	automobile	5	918	1	4	2	4	7	1	19	39
	bird	14	0	796	58	47	45	27	5	6	2
	cat	7	1	40	731	30	124	48	11	6	2
	deer	2	1	49	46	833	30	24	12	3	0
	dog	4	1	23	154	22	769	11	11	4	1
	frog	2	1	29	43	11	8	898	2	5	1
	horse	10	1	25	43	30	53	6	824	2	6
	ship	24	3	10	10	2	1	4	1	935	10
	truck	22	43	6	14	3	4	6	3	20	879
Predicted Label											
airplane automobile bird cat deer dog frog horse ship truck											

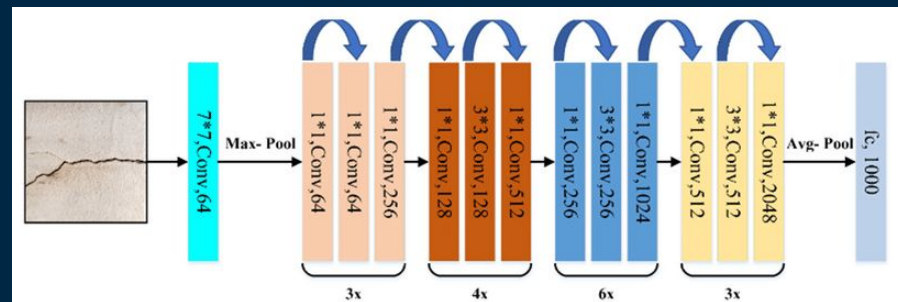
- Additional Batch Normalization, Dense, & Dropout layers
- Better precision with non-animal classes
- Challenge to differentiate between cats and dogs

# Transfer Learning with VGG16 and ResNet50 Pre-Trained Models

## VGG16 (86% test accuracy)



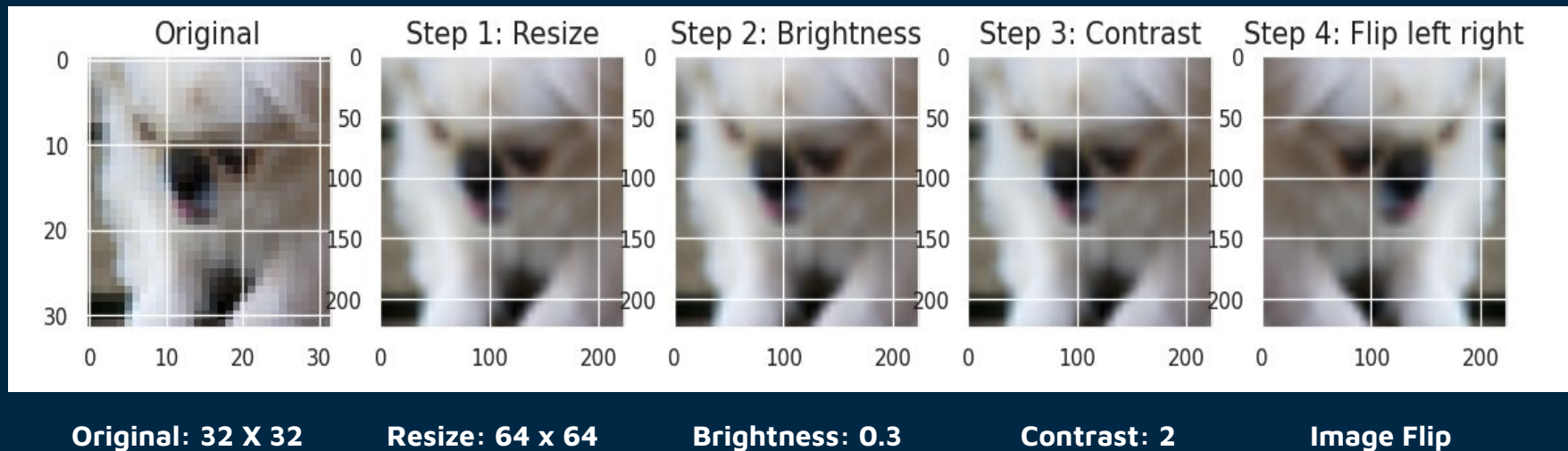
## ResNet50 (87% test accuracy)



- Both models pre-trained on ImageNet (1.2M  $224 \times 224$  images, 1000 classes)
- VGG16 (2014):** *shrinks kernel fields/pixel strides & adds convolutional layers*
- ResNet (2015):** *deep residual networks to solve for vanishing gradients problem*



# Pre-Processing & Data Augmentation Experiments





# Preprocessing improves accuracy & precision, but incurs significant compute costs

VGG16 **Without** Pre Processing:

True Label	airplane	884	21	17	4	0	0	4	7	40	23
	automobile	5	966	0	1	0	0	0	0	1	27
	bird	21	8	859	14	32	11	35	12	7	1
	cat	14	22	43	676	27	85	63	35	17	18
	deer	14	3	44	22	809	10	45	43	8	2
	dog	3	8	20	123	27	732	27	48	7	5
	frog	6	4	13	19	9	3	939	2	4	1
	horse	8	5	10	10	17	19	5	914	4	8
	ship	17	23	2	2	1	0	0	0	942	13
	truck	6	69	1	3	0	0	0	0	11	910
		airplane	automobile	bird	cat	deer	dog	frog	horse	ship	truck
Predicted Label											

Testing Accuracy: 84%  
Animal Precision: 81%

VGG16 **With** Pre Processing:

True Label	airplane	901	6	9	16	5	0	10	7	28	18
	automobile	0	972	0	1	0	0	2	0	0	25
	bird	11	1	918	17	15	9	17	9	3	0
	cat	1	0	13	901	5	34	33	7	2	4
	deer	0	0	16	30	895	17	20	22	0	0
	dog	0	0	4	111	6	837	23	17	0	2
	frog	1	1	6	8	0	0	983	0	0	1
	horse	1	0	1	9	6	13	2	966	0	2
	ship	13	6	2	1	0	0	5	0	962	11
	truck	0	30	0	2	0	0	0	1	4	963
		airplane	automobile	bird	cat	deer	dog	frog	horse	ship	truck
Predicted Label											

Testing Accuracy: 93% (+9%)  
Animal Precision: 91% (+10%)

# Pre-trained models & data pre-processing improves prediction accuracy, but our use case requires smaller models, faster processing times, better class precision

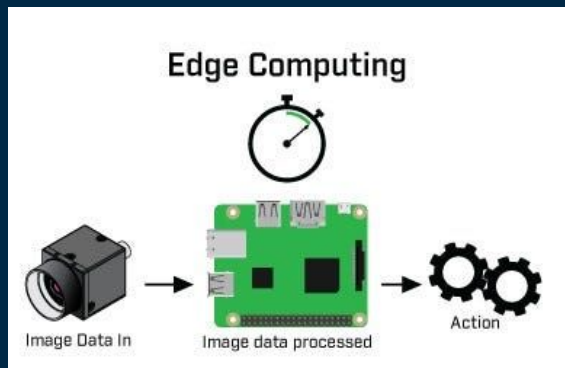
MODEL	TRAINING ACCURACY	VALIDATION ACCURACY	TEST ACCURACY	#LAYERS	ACTIVATION	OPTIMIZER	#PARAMETERS	PROCESSING TIME	ANIMAL PRECISION	NON-ANIMAL PRECISION
FFNN	.5377	.4936	.4931	1	relu	Adam	3,157,002	40s		
CNN1	.8765	.7118	.7037	8	relu	Adam	1,757,002	60s		
CNN2	.8484	.7450	.7339	13	relu	Adam	5,411,370	60s		
CNN3	.9423	.8428	.8366	23	relu	Adam	8,438,858	80s	.8197	.9343
CNN3 + Pre-Processing	.9756	.9107	.8341	23	relu	Adam	21,021,770	620s	.8087	.9335
VGG16 v4	.9943	.8612	.8563	16+7	relu	SGD	16,299,850	200s	.8337	.9388
VGG16 v4 + Pre-Processing	.9698	.9846	.9298	16+7	relu	SGD	17,872,714	2400s	.9213	.9642
ResNet50 v4	.9626	.8818	.8740	50+10	relu	Adam	26,745,738	1450s	.8626	.9490

**Note:** Data pre-processing steps includes resized training images to 64x64 resolution, adjusted image brightness (0.3), adjusted contrast factor (2), and randomly flipped training images.

**Performance improvements of pre-trained models, data pre-processing not worth >10x training time required.**

# Summary Takeaways, Ethical Considerations & Limitations

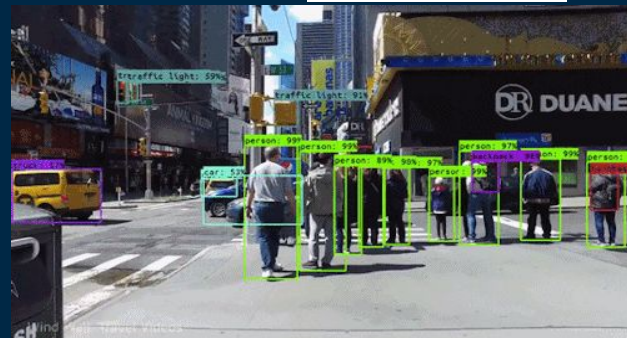
## Summary Takeaway: CNN v3 is optimal for our use case



## ML in edge devices like cameras requires:

1. Smaller models
2. Shorter processing times
3. Better precision between classes

## Ethical Considerations & Limitations



Pay As You Go	Recommended Colab Pro	Colab Pro+
<p>\$5.99 for 100 Compute Units</p> <p>\$49.99 for 500 Compute Units</p> <p>You currently have 0 compute units.</p> <ul style="list-style-type: none"><li>✓ No subscription required. Only pay for what you use.</li><li>✓ Faster GPUs Upgrade to more powerful premium GPUs.</li></ul>	<p>\$59.99 / month</p> <ul style="list-style-type: none"><li>✓ 100 compute units per month Compute units expire after 90 days. Purchase more as you need them.</li><li>✓ Faster GPUs Upgrade to more powerful premium GPUs.</li><li>✓ More memory Access our higher memory machines.</li></ul>	<p>\$49.99 / month</p> <ul style="list-style-type: none"><li>✓ 500 compute units per month Compute units expire after 90 days. Purchase more as you need them.</li><li>✓ Faster GPUs Priority access to upgrade to more powerful premium GPUs.</li><li>✓ More memory Access our higher memory machines.</li><li>✓ Background execution Upgrade your notebooks to keep executing for up to 24 hours even if you close your browser.</li></ul>

The background is a dark blue gradient. It is decorated with various geometric elements: thin white vertical lines of varying lengths, small squares in teal, orange, and pink, and larger squares in teal and pink. Some squares are solid, while others are outlined in white. The word "Questions?" is centered in a large, white, sans-serif font.

# Questions?