



# Applications of Deep Learning in Heliophysics

Andrés Muñoz-Jaramillo

[www.solardynamo.org](http://www.solardynamo.org)

# What is deep learning?



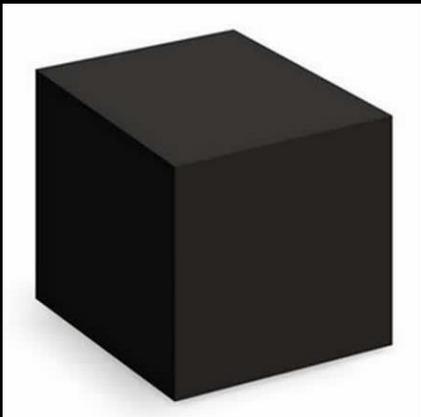
What business people think it is



What neophytes think it is



What it really is



What skeptics think it is



What the public thinks it is



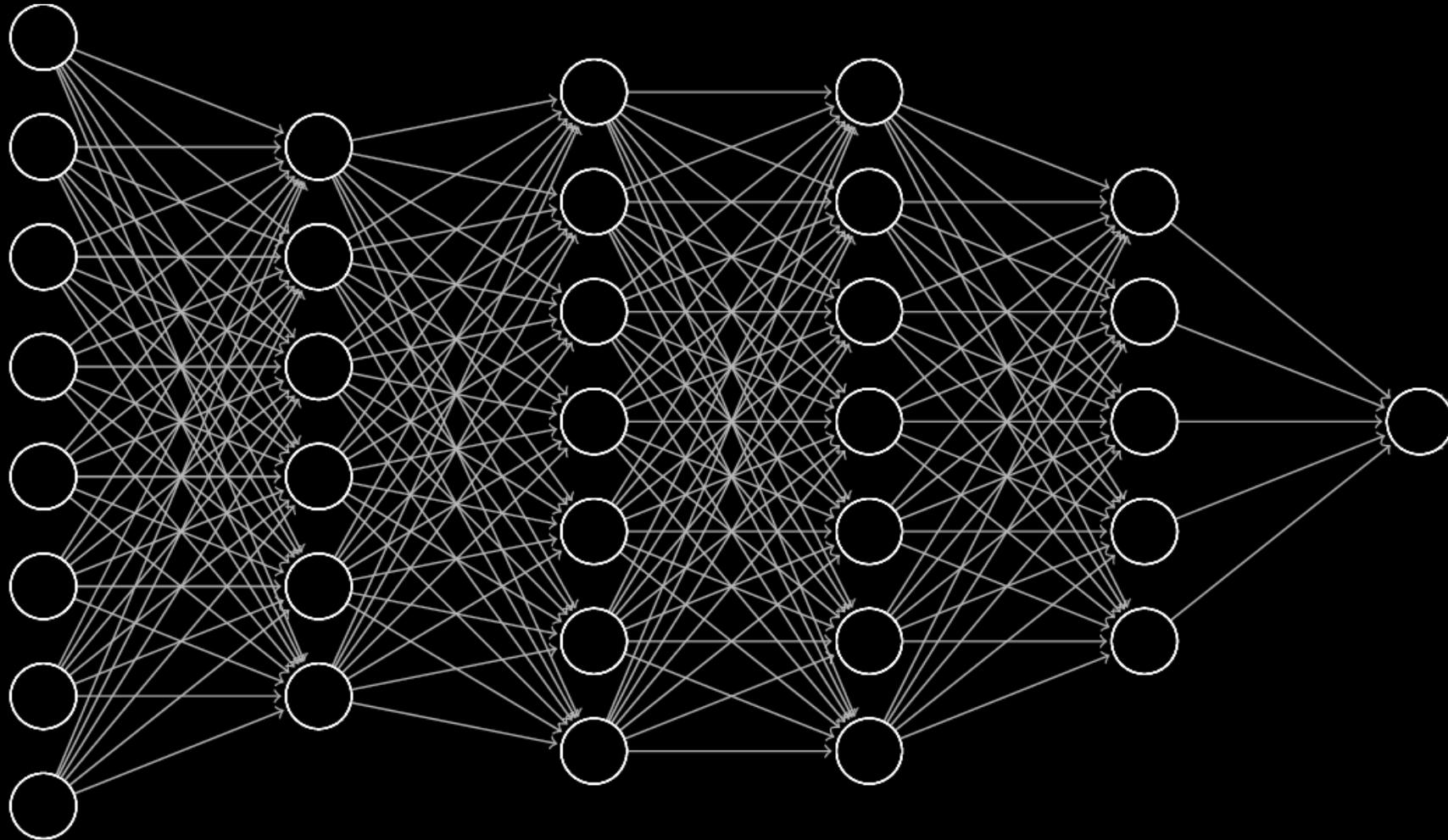
A tool that helps us find new things in our data

# What is deep learning?\*

A class of machine learning algorithms that:

- Use a cascade of multiple layers of nonlinear processing units for feature extraction and transformation.
- Learn multiple levels of representations that correspond to different levels of abstraction (i.e. the levels form a hierarchy of concepts).

# What is deep learning?\*

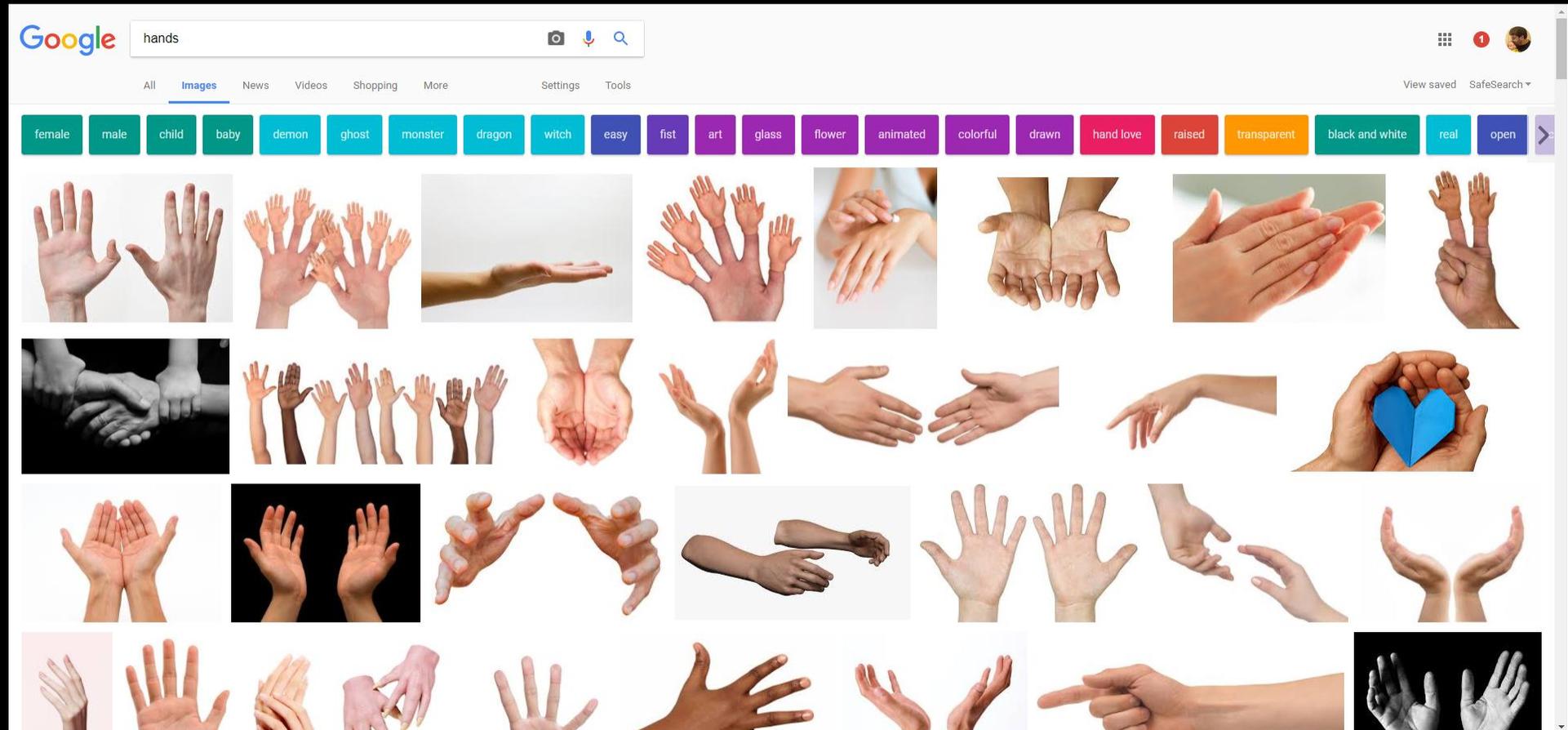


\* Taken from Wikipedia

# Why deep learning?

**Count how many times  
the players wearing  
white pass the ball**

# Deep learning has important limitations too



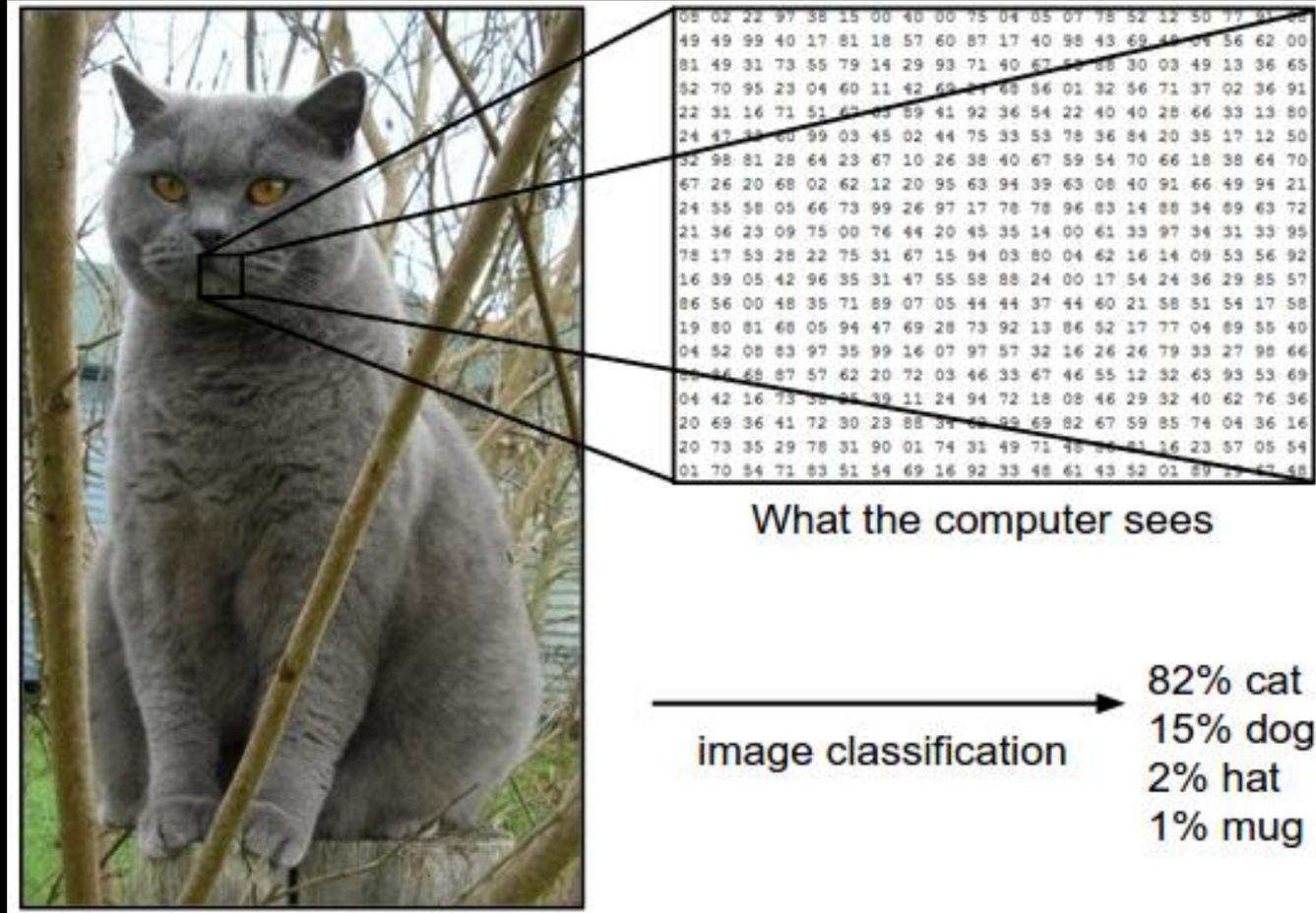
# Deep learning has important limitations too



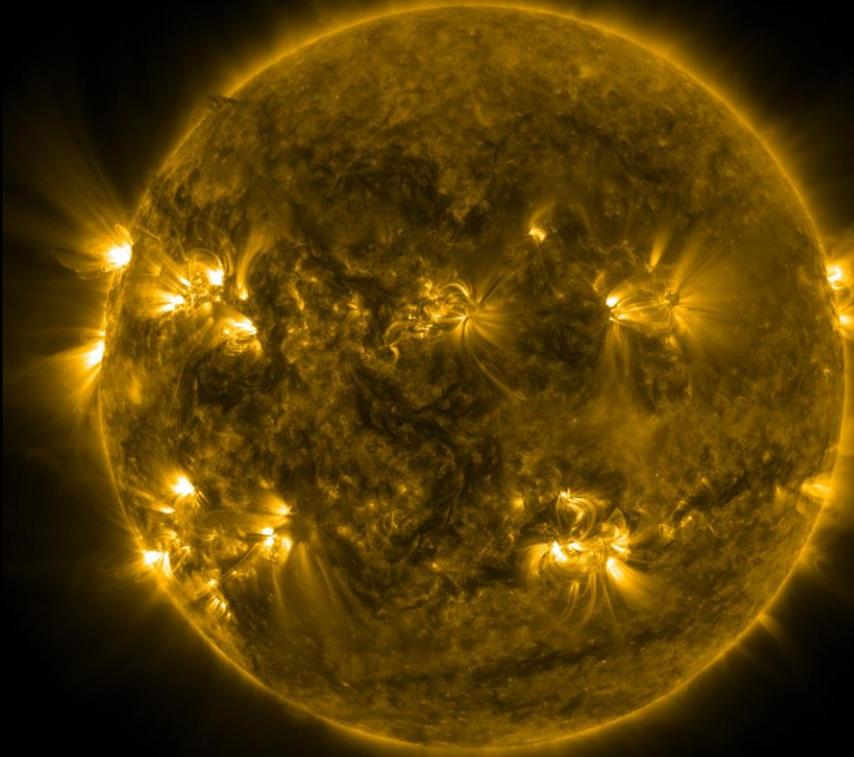
# Deep learning has Important limitations too

- Deep learning algorithms are naïve and single-minded in the way they learn.
- Training data selection is absolutely critical for their success.

# Deep learning and image data



# Deep learning and image data



08	02	22	97	38	15	00	40	00	75	04	05	07	78	52	12	50	77	01	82
49	49	99	40	17	81	18	57	60	87	17	40	98	43	69	40	54	56	62	00
81	49	31	73	55	79	14	29	93	71	40	67	55	88	30	03	49	13	36	65
52	70	95	23	04	60	11	42	69	24	68	56	01	32	56	71	37	02	36	91
22	31	16	71	51	65	85	89	41	92	36	54	22	40	40	28	66	33	13	80
24	47	33	00	99	03	45	02	44	75	33	53	78	36	84	20	35	17	12	50
32	98	81	28	64	23	67	10	26	38	40	67	59	54	70	66	18	38	64	70
67	26	20	68	02	62	12	20	95	63	94	39	63	08	40	91	66	49	94	21
24	35	38	05	66	73	99	26	97	17	78	78	96	83	14	88	34	89	63	72
21	36	23	09	75	00	76	44	20	45	35	14	00	61	33	97	34	31	33	95
78	17	53	28	22	75	31	67	15	94	03	80	04	62	16	14	09	53	56	92
16	39	05	42	96	35	31	47	55	58	88	24	00	17	54	24	36	29	85	57
86	56	00	48	35	71	89	07	05	44	44	37	44	60	21	58	31	54	17	58
19	80	81	68	05	94	47	69	28	73	92	13	86	52	17	77	04	89	55	40
04	52	08	83	97	35	99	16	07	97	57	32	16	26	26	79	33	27	98	66
09	46	68	87	57	62	20	72	03	46	33	67	46	55	12	32	63	93	53	69
04	42	16	73	51	85	39	11	24	94	72	18	08	46	29	32	40	62	76	36
20	69	36	41	72	30	23	88	34	60	89	69	82	67	59	85	74	04	36	16
20	73	35	29	78	31	90	01	74	31	49	71	45	85	81	16	23	57	05	54
01	70	54	71	83	51	54	69	16	92	33	48	61	43	52	01	89	27	67	48

What the computer sees

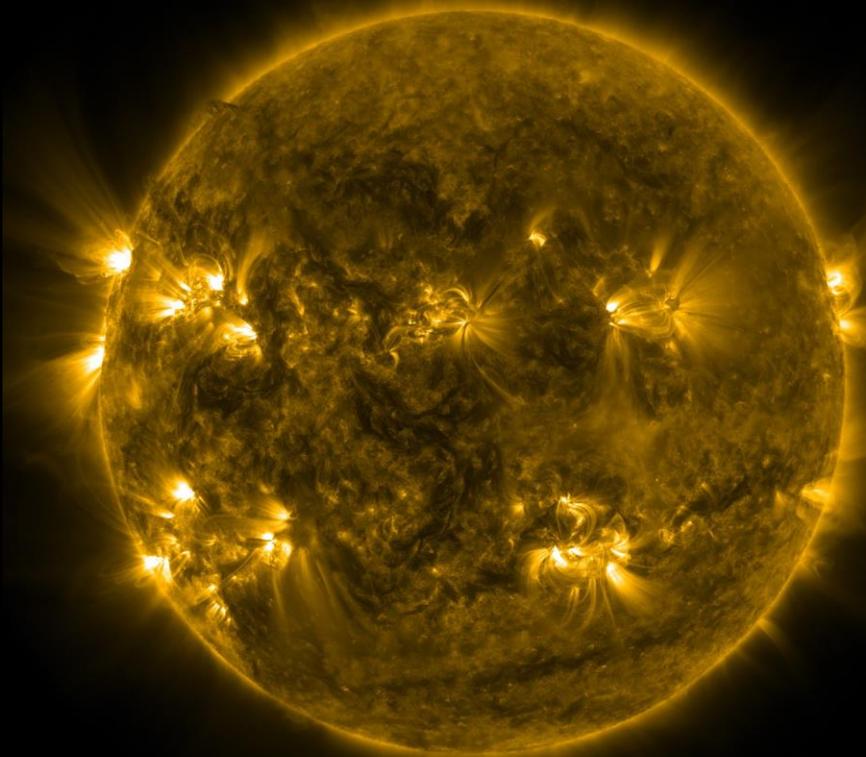
image classification

82% cat  
15% dog  
2% hat  
1% mug

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[cs231n.github.io/classification](https://cs231n.github.io/classification)

# Deep learning and image data



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19	80	81	68	05	94	47	69	28	73	92	13	86	52	17	77	04	89	55	40
04	52	08	83	97	35	99	16	07	97	57	32	16	26	26	79	33	27	98	66
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04	42	16	73	51	85	39	11	24	94	72	18	08	46	29	32	40	62	76	36
20	69	36	41	72	30	23	88	34	60	89	69	82	67	59	85	74	04	36	16
20	73	35	29	78	31	90	01	74	31	49	71	45	55	81	16	23	57	05	54
01	70	54	71	83	51	54	69	16	92	33	48	61	43	52	01	89	27	67	48

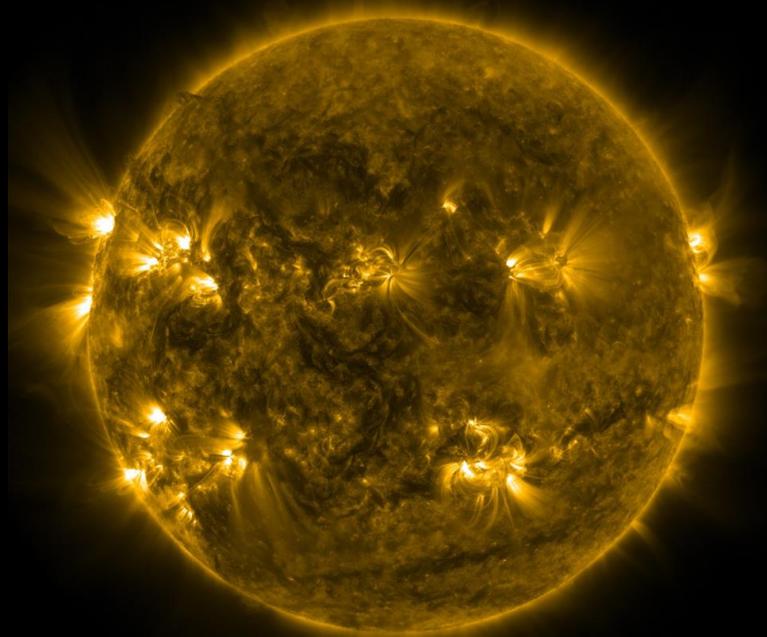
What the computer sees

EUV Irradiance

$3.2 \times 10^{-5}$   
 $\text{W m}^{-2}$

# Convolutional Neural Networks

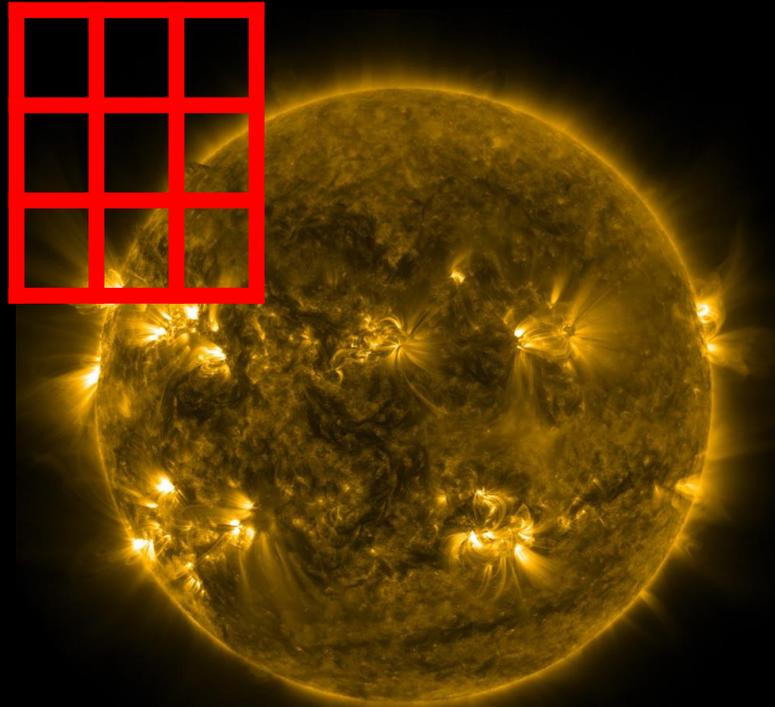
Neural networks with layers made of tunable convolution filters



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# Convolutional Neural Networks

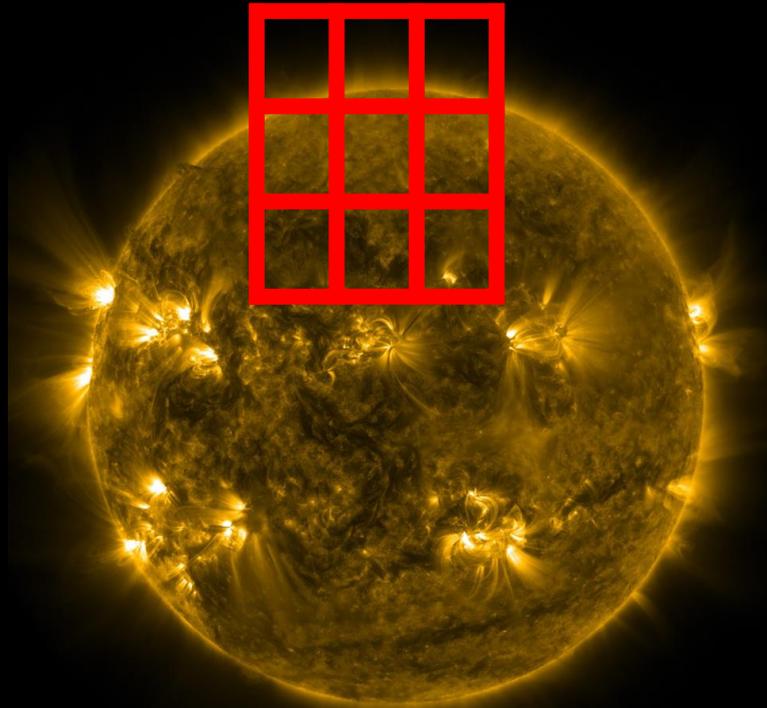
Neural networks with layers made of tunable convolution filters



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# Convolutional Neural Networks

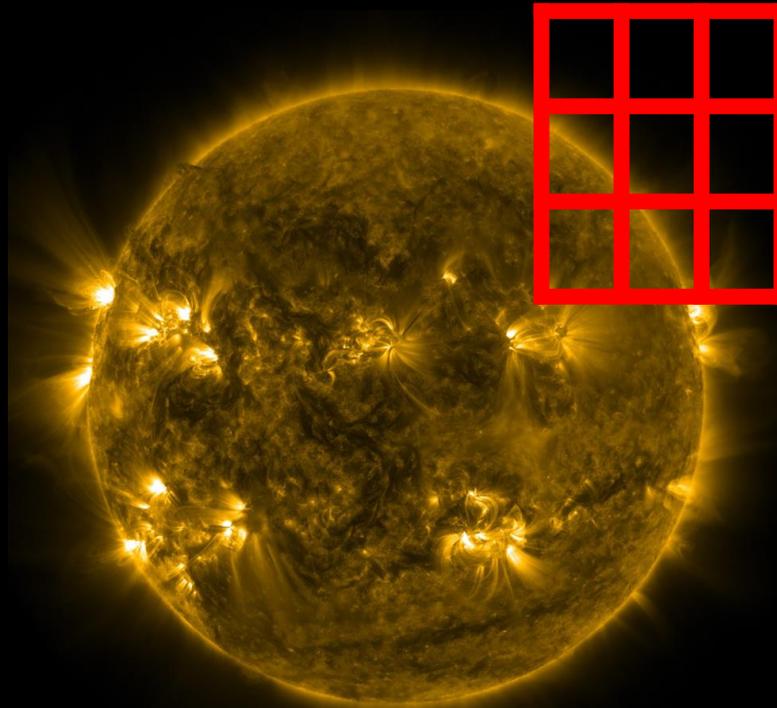
Neural networks with layers made of tunable convolution filters



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# Convolutional Neural Networks

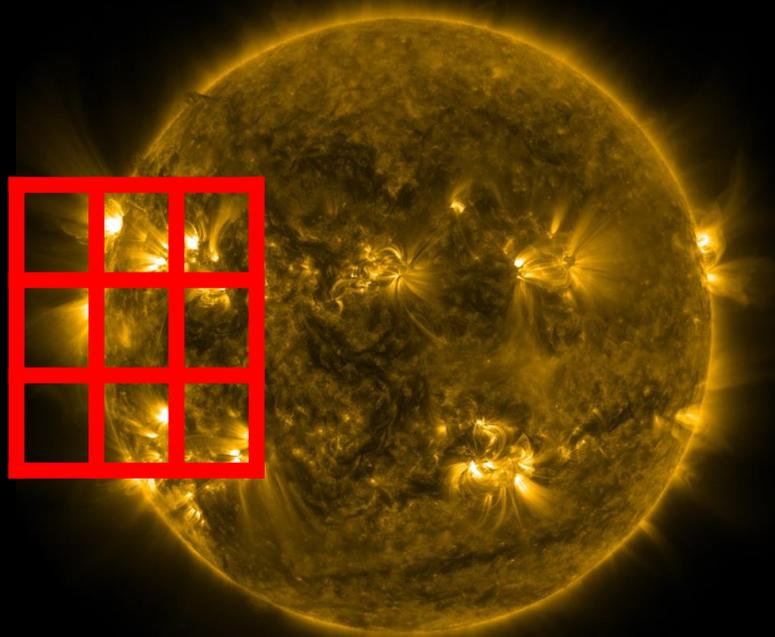
Neural networks with layers made of tunable convolution filters



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# Convolutional Neural Networks

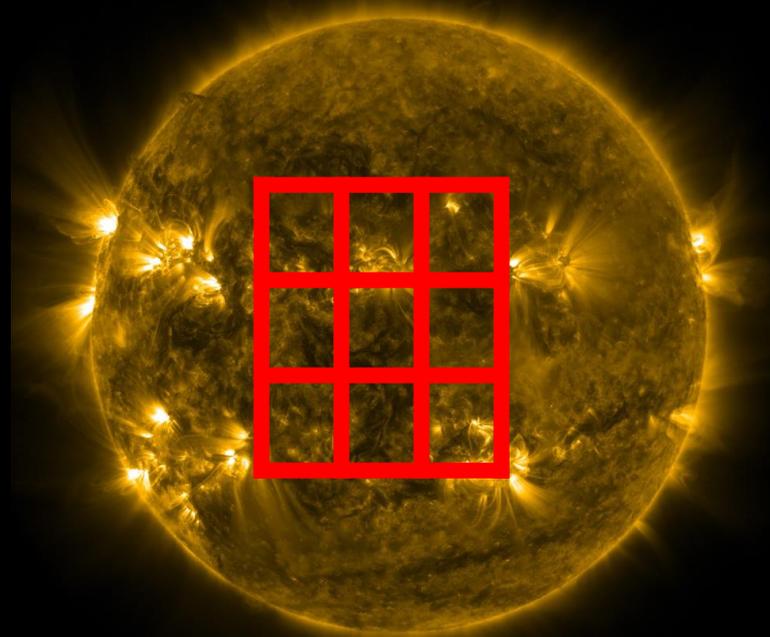
Neural networks with layers made of tunable convolution filters



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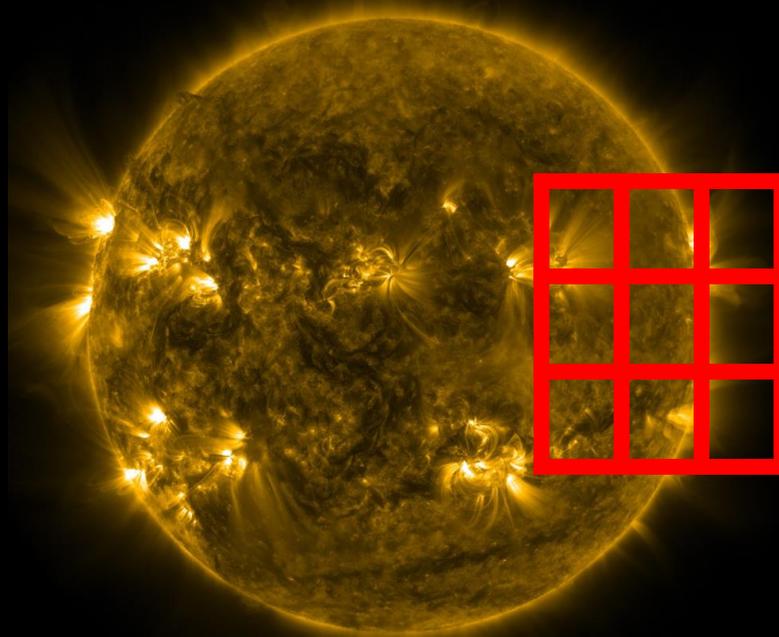
Neural networks with layers made of tunable convolution filters



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# Convolutional Neural Networks

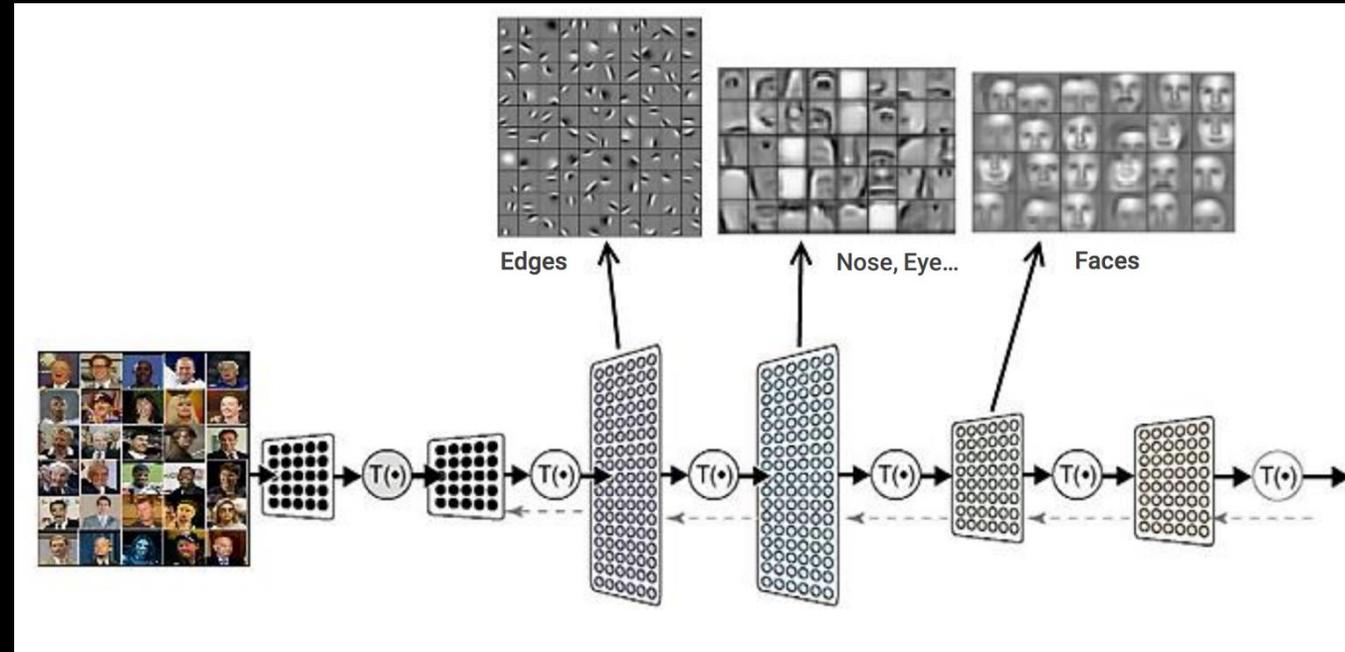
Neural networks with layers made of tunable convolution filters



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# Convolutional Neural Networks

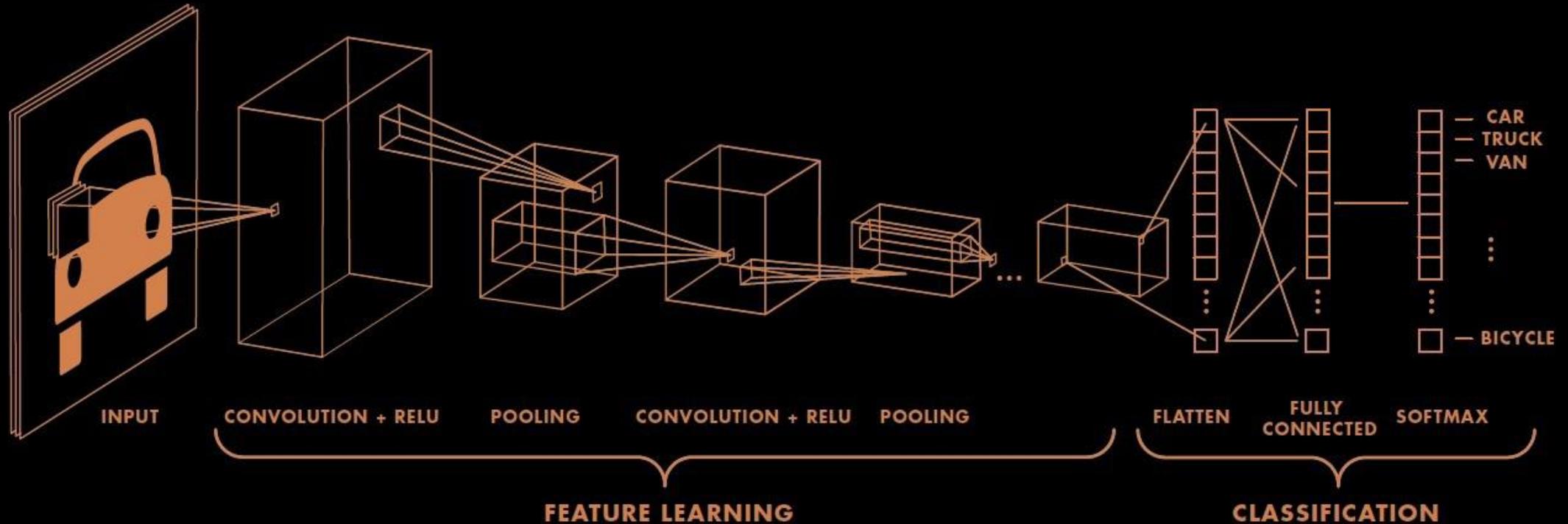
Neural networks with layers made of tunable convolution filters



Several convolutional layers allow the neural network to recognize features of increased complexity

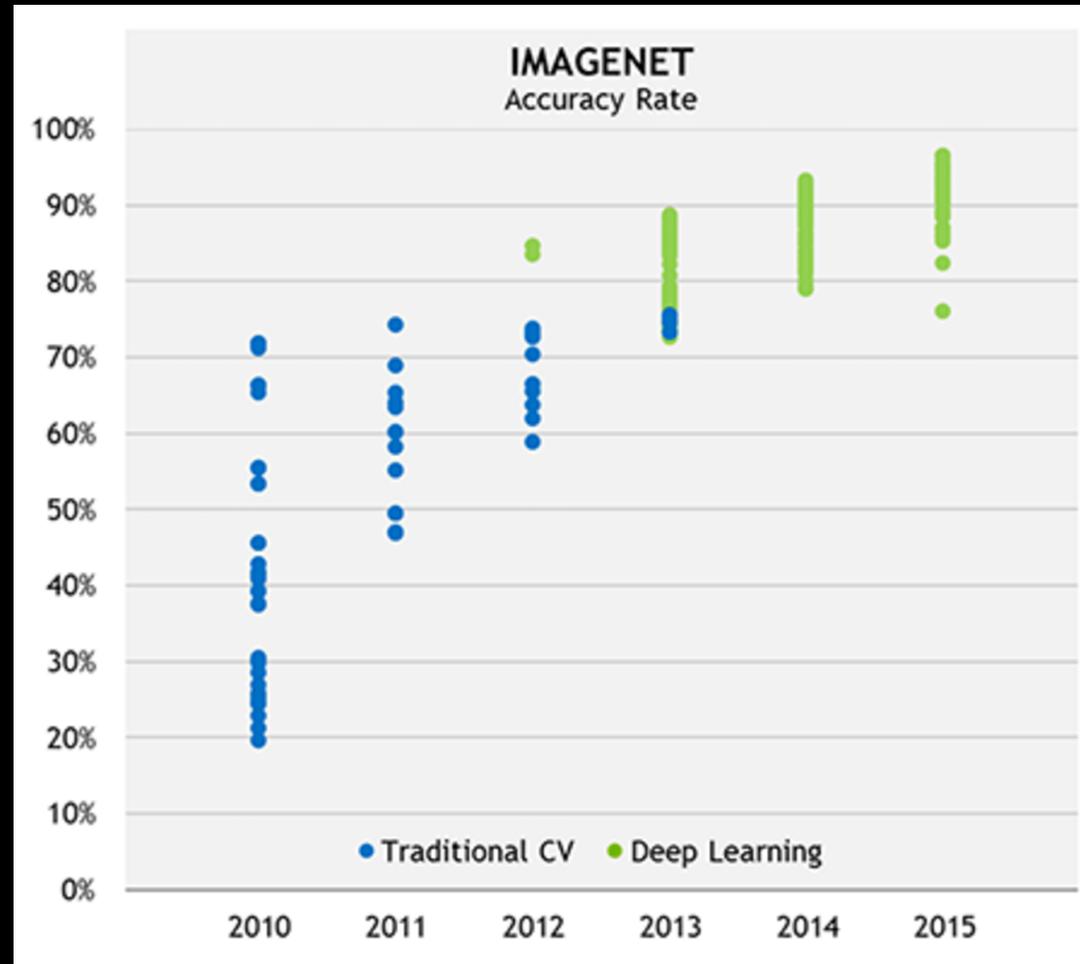
# Convolutional Neural Networks

Neural networks with layers made of tunable convolution filters



Several convolutional layers allow the neural network to recognize features of increased complexity

# Convolutional Neural Networks



CNNs have revolutionized the way we do image classification.

# Grad-CAM: Why did you say that?

## Visual Explanations from Deep Networks via Gradient-based Localization

Ramprasaath R. Selvaraju    Abhishek Das    Ramakrishna Vedantam    Michael Cogswell  
Devi Parikh    Dhruv Batra  
Virginia Tech

{ram21, abhshkdz, vrama91, cogswell, parikh, dbatra}@vt.edu

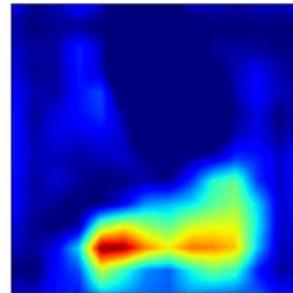
391v1 [cs.CV] 7 Oct 2016



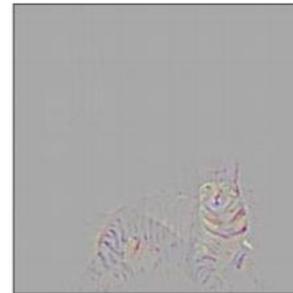
(a) Original Image



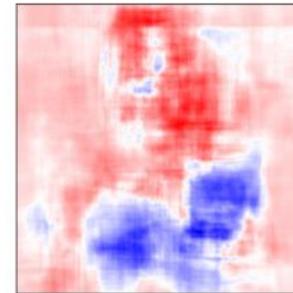
(b) Guided Backprop for 'Cat'



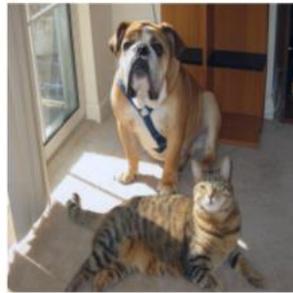
(c) Grad-CAM for 'Cat'



(d) Guided Grad-CAM for 'Cat'



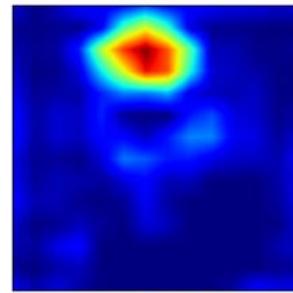
(e) Occlusion Map for 'Cat'



(f) Original Image



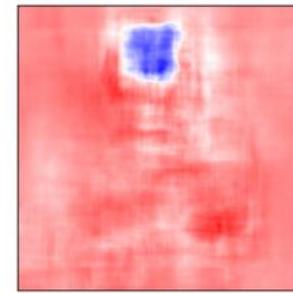
(g) Guided Backprop for 'Dog'



(h) Grad-CAM for 'Dog'



(i) Guided Grad-CAM for 'Dog'



(j) Occlusion Map for 'Dog'

NEURAL NETWORKS ARE NOT BLACK BOXES AND  
CAN BE MINED FOR SCIENTIFIC INSIGHT