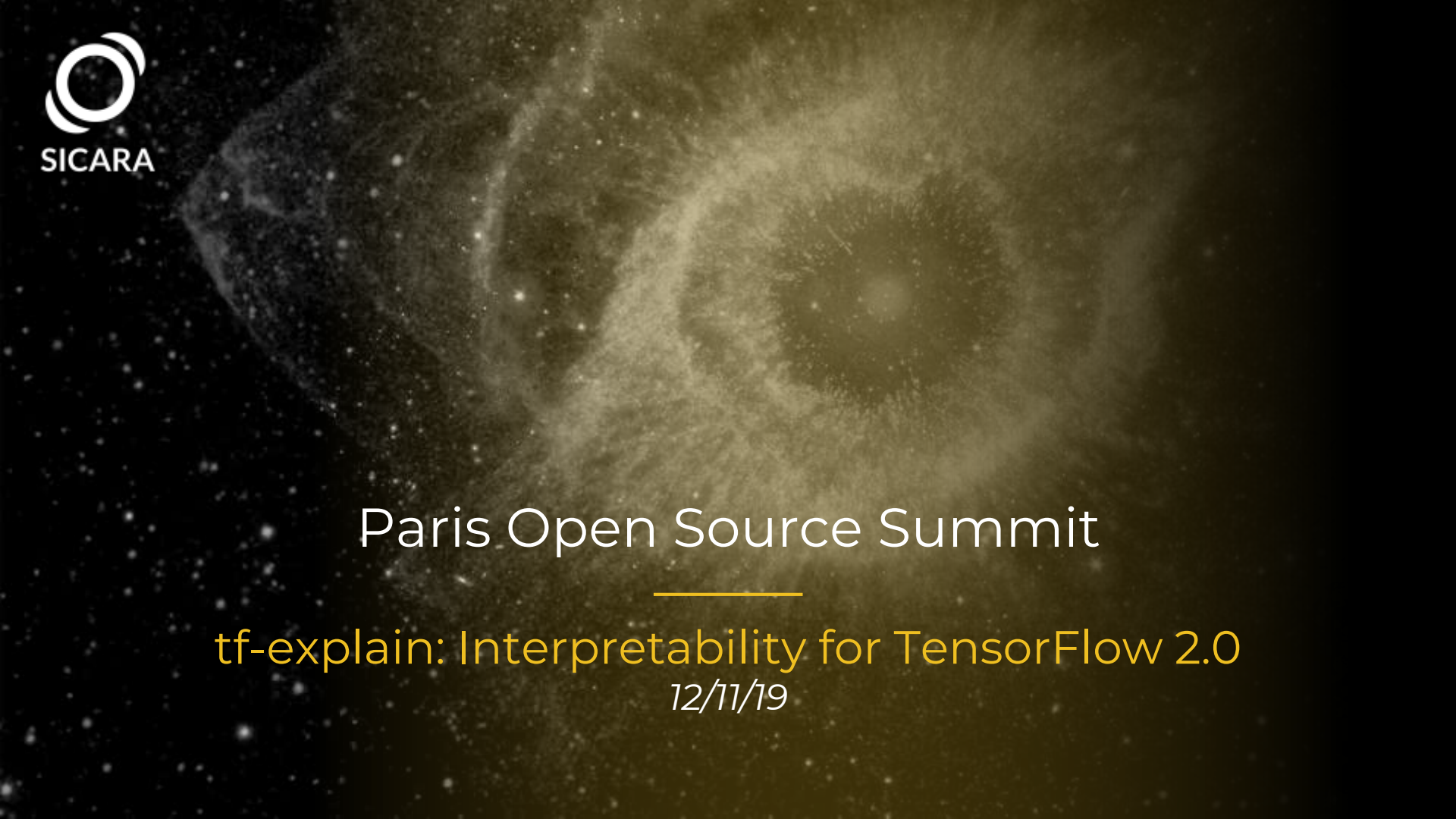

Paris Open Source Summit

tf-explain: Interpretability for TensorFlow 2.0

12/11/19

cofondateur & CTO

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Thanks to

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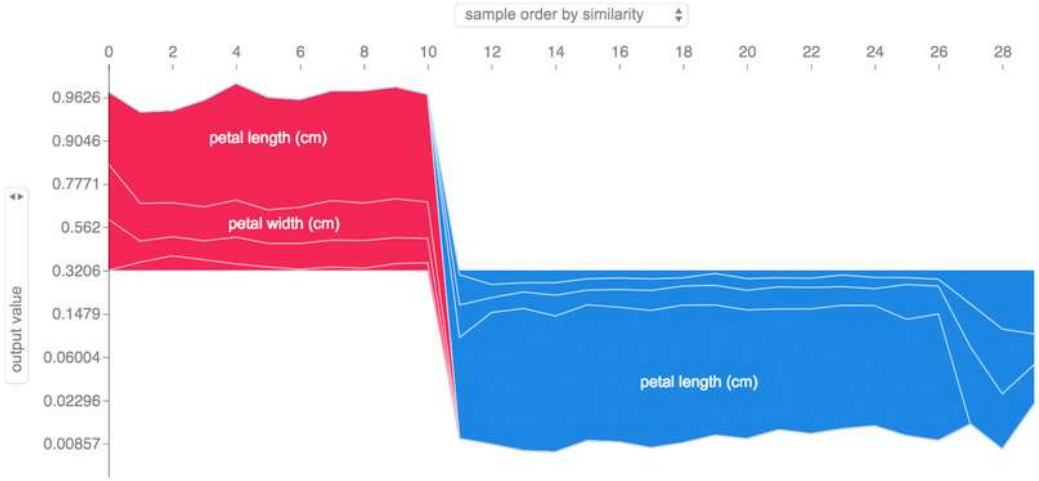
@raphaelmeudec

tf-explain

Introduction

Interpretability
Linear models

	sepal length (cm)	sepal width (cm)	petal length (cm)	petal width (cm)
0	5.1	3.5	1.4	0.2
1	4.9	3.0	1.4	0.2
2	4.7	3.2	1.3	0.2
3	4.6	3.1	1.5	0.2
4	5.0	3.6	1.4	0.2
...	...	...	...	...
145	6.7	3.0	5.2	2.3
146	6.3	2.5	5.0	1.9
147	6.5	3.0	5.2	2.0
148	6.2	3.4	5.4	2.3
149	5.9	3.0	5.1	1.8



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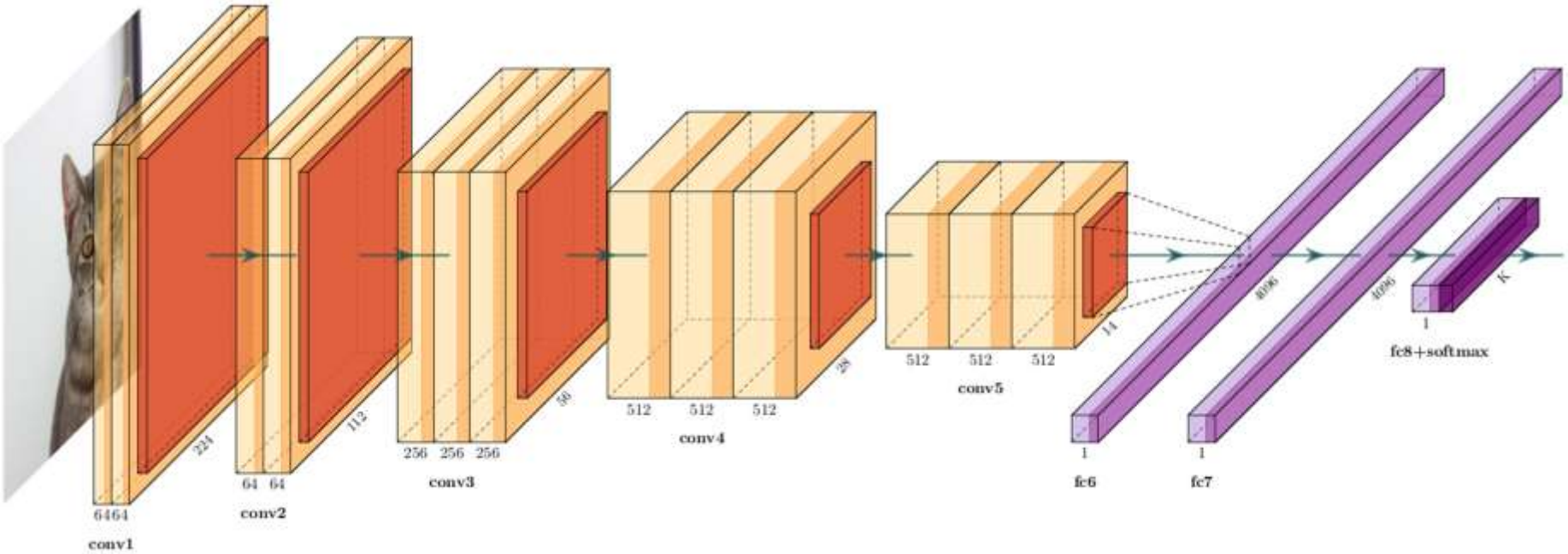
Interpretability
Deep networks



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Interpretability

Provide explanations on a neural network's decisions

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TF2.0

TF 2.0
Keras as the main entrypoint

Stable release: 10/01/2019

Sequential API

Functional API

Subclassing API

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Gradient Descent

2.0 - Record operations in tf.GradientTape context

```python
# TensorFlow 2.0
import numpy as np
import tensorflow as tf

num_samples = 4
dimension = 3

x = tf.convert_to_tensor(np.random.random((num_samples, dimension)), dtype=tf.float32)
y = tf.one_hot(np.random.randint(2, size=(num_samples,)), depth=2)

model = tf.keras.Sequential([
    tf.keras.layers.Dense(2, activation='softmax', input_shape=(dimension,))
])

model.compile(loss='binary_crossentropy', optimizer='adam')

optimizer = tf.keras.optimizers.Adam()

with tf.GradientTape() as tape:
    output = model(x)
    loss = tf.losses.binary_crossentropy(output, y)
    print(loss)
    # >> tf.Tensor([ 9.7544365  7.3376875 10.41608   10.882192 ], shape=(4,), dtype=float32)

grads = tape.gradient(loss, model.trainable_variables)

optimizer.apply_gradients(zip(grads, model.trainable_variables))
```

Create model

Compute loss in tf.GradientTape context

Run optimizer with recorded gradients

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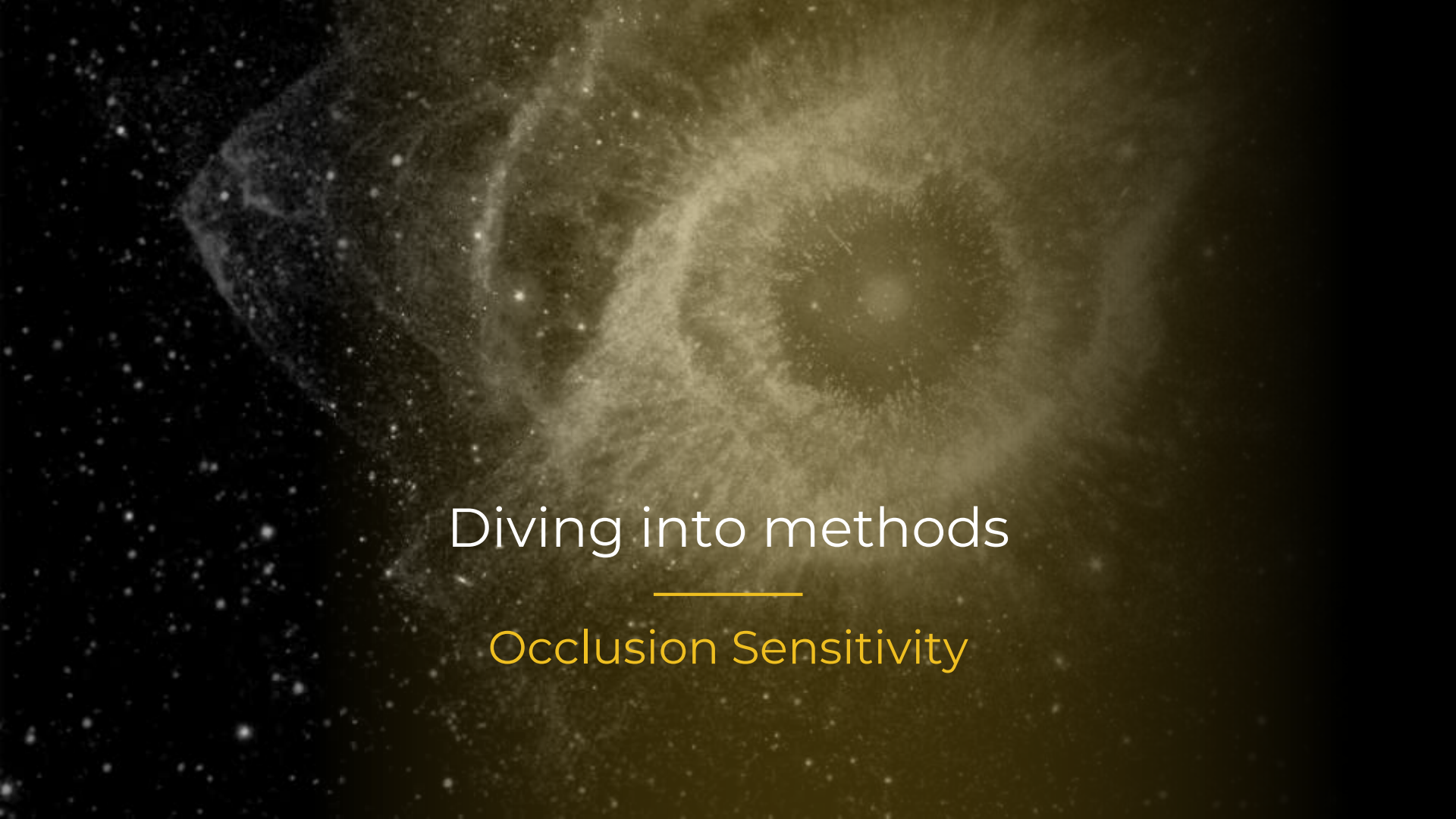
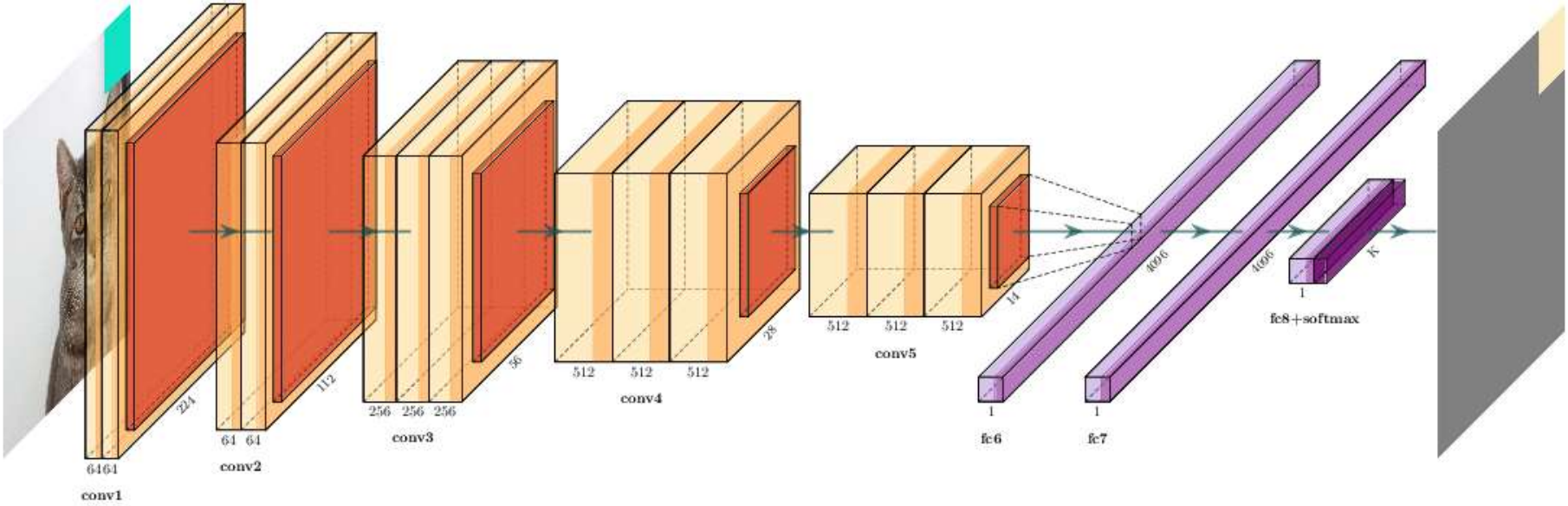

Diving into methods
Occlusion Sensitivity

Method #1: Occlusion Sensitivity

Hide parts iteratively to determine its importance



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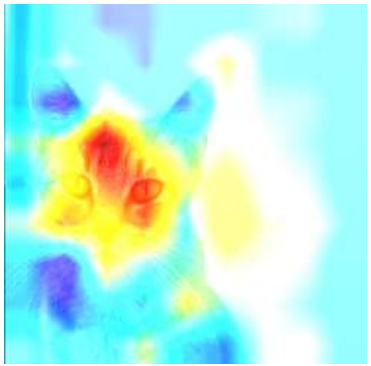
Method #1: Occlusion Sensitivity

Hide parts iteratively to determine its importance

```python
import numpy as np
import tensorflow as tf
from tf_explain.utils.image import apply_grey_patch

IMAGE_PATH = "./img/cat.jpg"
PATCH_SIZE = 10
TABBY_CAT_CLASS_INDEX = 281

# Load target image
img = tf.keras.preprocessing.image.load_img(IMAGE_PATH, target_size=(224, 224))
img = tf.keras.preprocessing.image.img_to_array(img)

# Load model
model = tf.keras.applications.vgg16.VGG16(weights="imagenet", include_top=True)

patches = [
    apply_grey_patch(img, top_left_x, top_left_y, PATCH_SIZE)
    for index_x, top_left_x in enumerate(range(0, img.shape[0], PATCH_SIZE))
    for index_y, top_left_y in enumerate(range(0, img.shape[1], PATCH_SIZE))
]

predictions = model.predict(np.array(patches), batch_size=16)
target_class_predictions = [
    prediction[TABBY_CAT_CLASS_INDEX] for prediction in predictions
]

coordinates = [
    (index_y, index_x)
    for index_x, _ in enumerate(range(0, img.shape[0], PATCH_SIZE))
    for index_y, _ in enumerate(range(0, img.shape[1], PATCH_SIZE))
]

sensitivity_map = np.zeros((img.shape[0] // PATCH_SIZE, img.shape[1] // PATCH_SIZE))
for (index_y, index_x), confidence in zip(
        coordinates, target_class_predictions
):
    sensitivity_map[index_y, index_x] = 1 - confidence
```



Create patched images

Predict patches

Create output map

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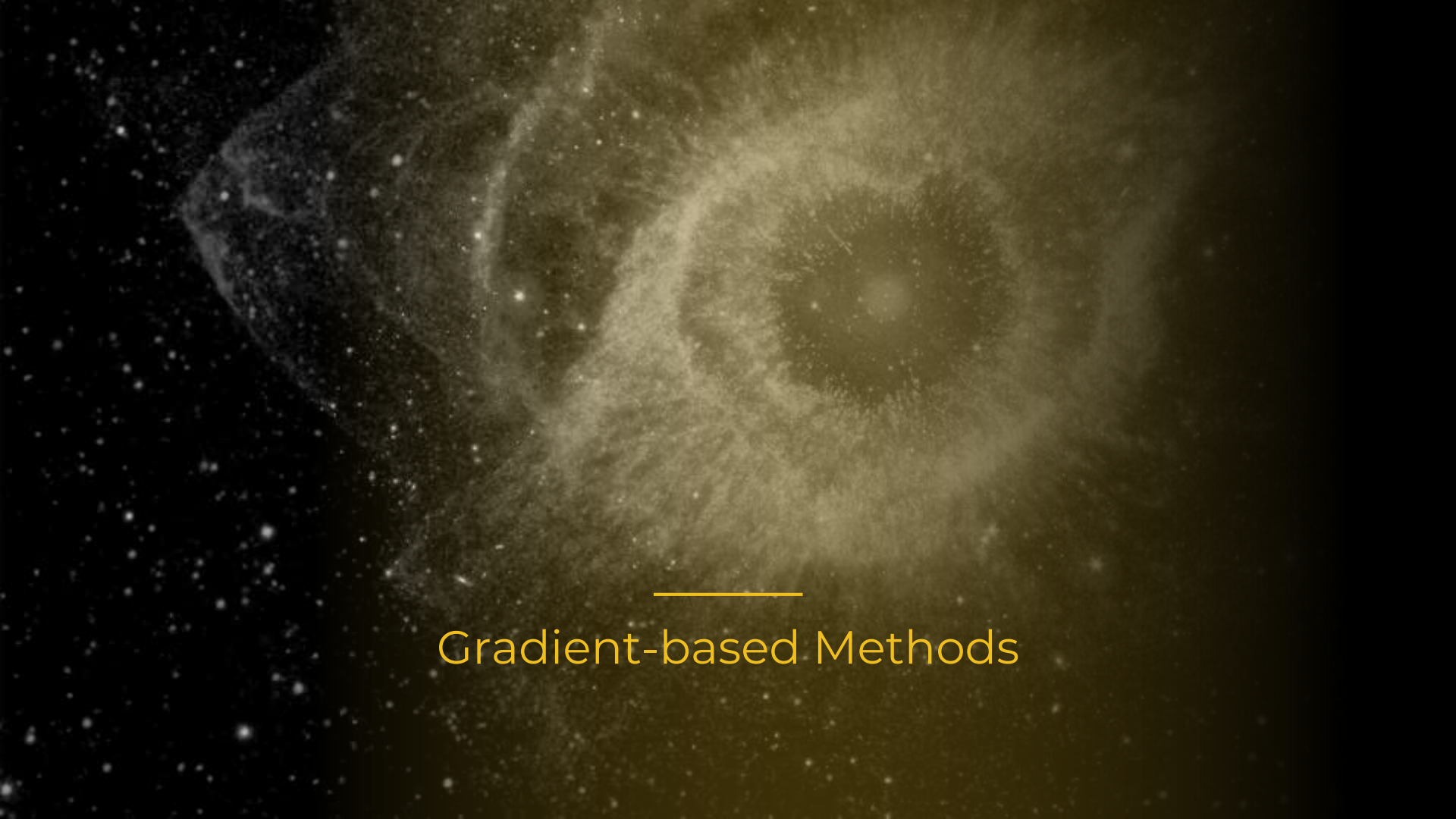
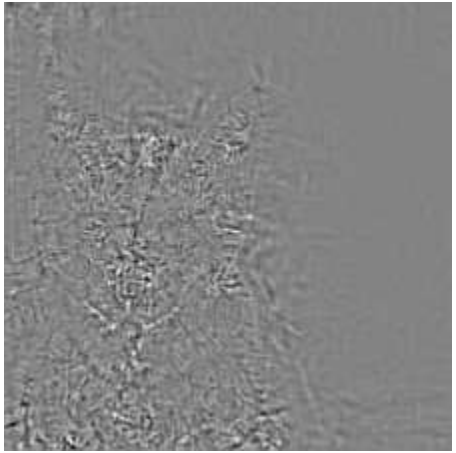


Gradient-based Methods

Method #2: Vanilla Gradients

Input image

Gradients for
“Cat” class



Understanding Neural Networks Through Deep Visualization | Jason Yosinski, Jeff Clune, Anh Nguyen, Thomas Fuchs, Hod Lipson

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Method #2: Vanilla Gradients

```python
import tensorflow as tf

IMAGE_PATH = './img/cat.jpg'
TABBY_CAT_CLASS_INDEX = 281

# Load target image
img = tf.keras.preprocessing.image.load_img(IMAGE_PATH, target_size=(224, 224))
img = tf.keras.preprocessing.image.img_to_array(img)

# Load model
model = tf.keras.applications.vgg16.VGG16(weights='imagenet', include_top=True)

num_classes = model.output.shape[1]
expected_output = tf.one_hot([TABBY_CAT_CLASS_INDEX], num_classes)

# Compute Gradients
with tf.GradientTape() as tape:
    inputs = tf.cast([img], tf.float32)
    tape.watch(inputs)
    predictions = model(inputs)
    loss = tf.keras.losses.categorical_crossentropy(
        expected_output, predictions
    )

gradients = tape.gradient(loss, inputs)[0]
```

Load sample data

Define expected output as one hot vector

Compute gradients with respect to the expected class

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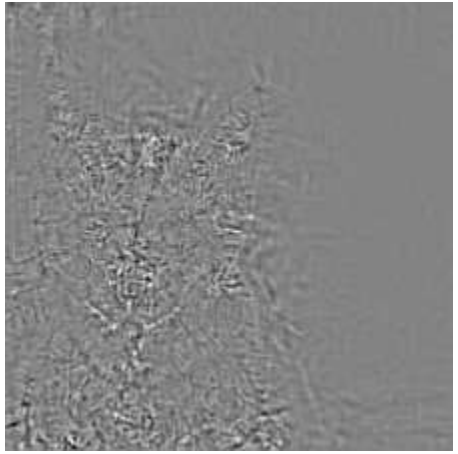
Flaws in Interpretability

What's the point?

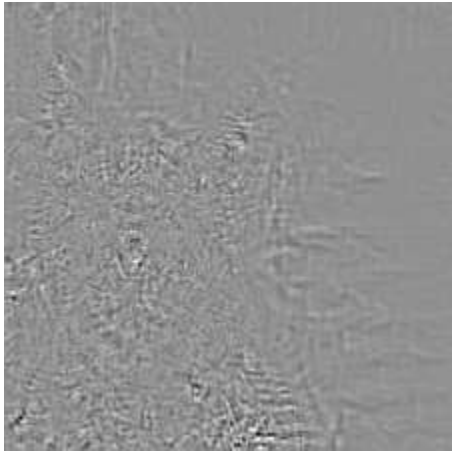
Gradients are open to interpretation

Input image

Gradients for "Cat" class



Gradients for "Kite" class



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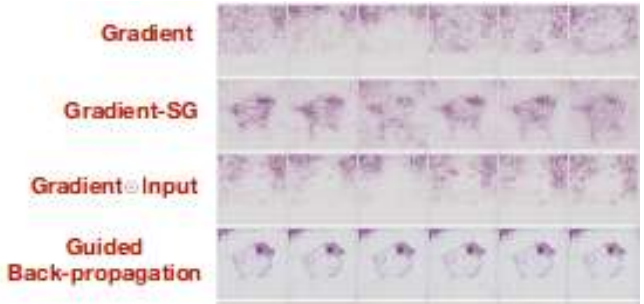
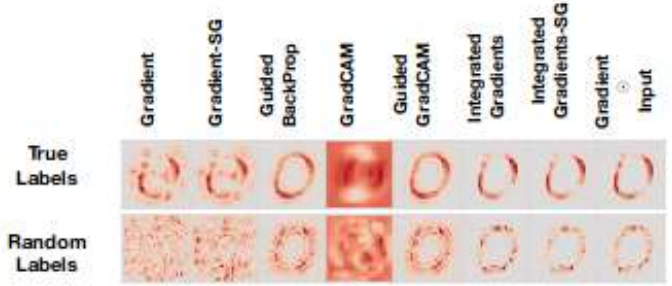
Checks for saliency maps



Parameters Randomization



Data Randomization

[Sanity Checks for Saliency Maps] | Julius Adebayo, Justin Gilmer, Michael Muelly, Ian Goodfellow, Moritz Hardt, Been Kim

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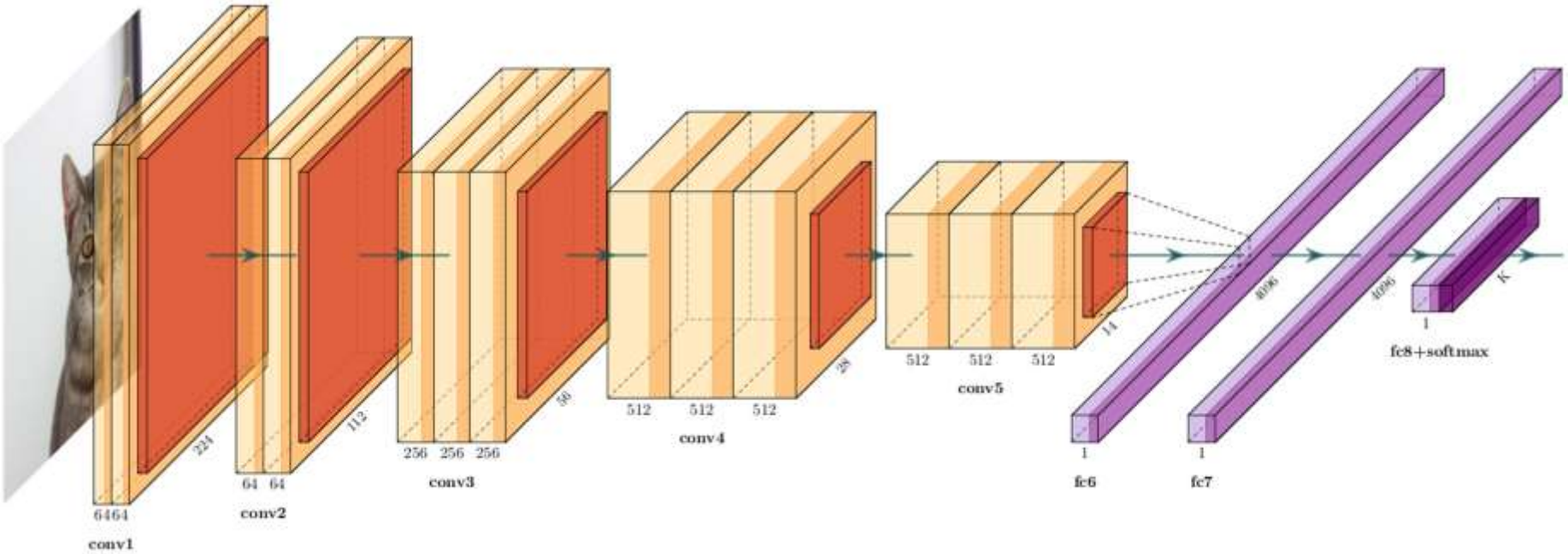
Grad CAM

Method #3: Grad CAM



Grad-CAM: Gradient-weighted Class Activation Mapping | Ramprasaath R. Selvaraju, Michael Cogswell, Abhishek Das, Ramakrishna Vedantam, Devi Parikh, Dhruv Batra

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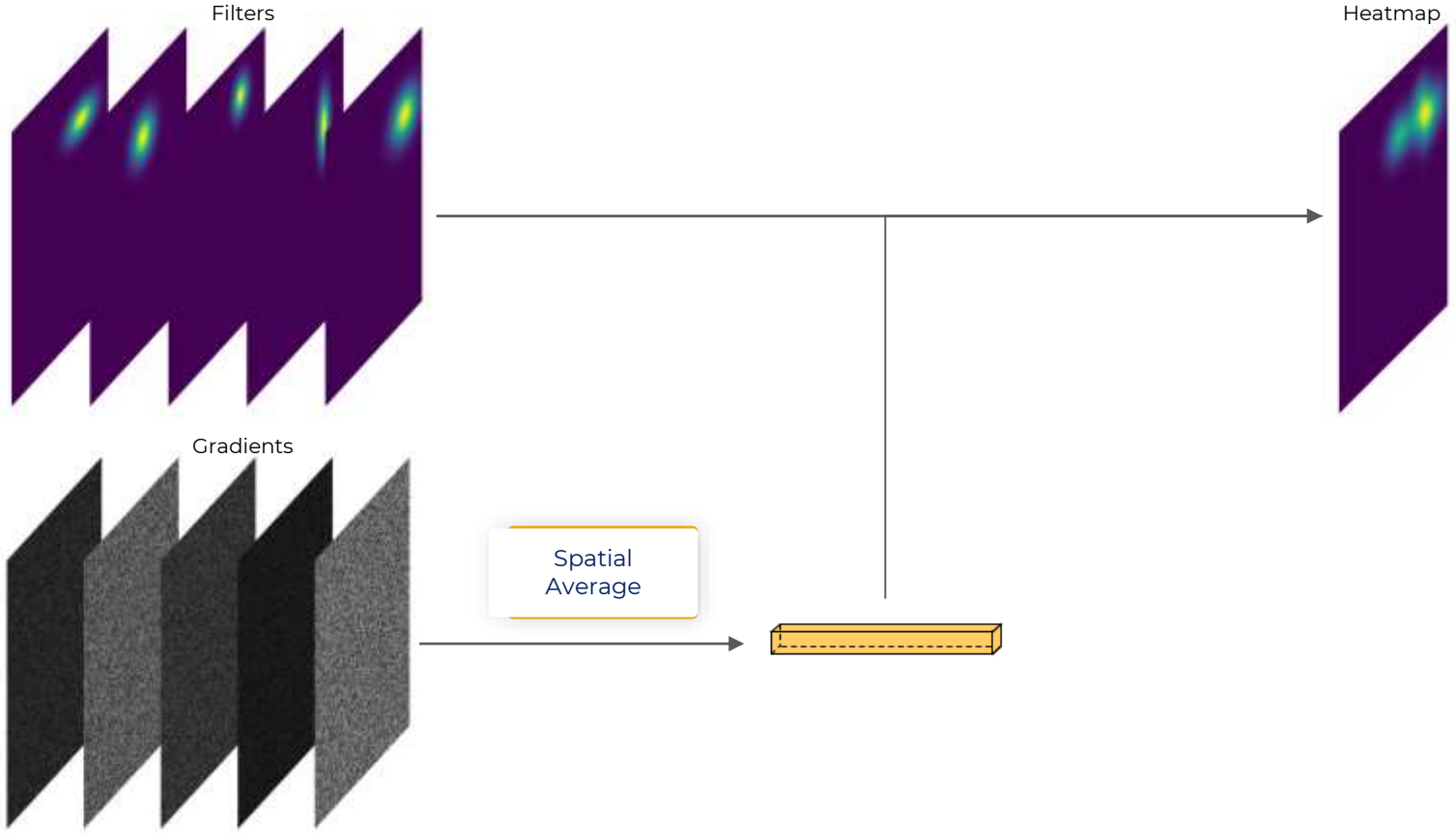
Method #3: Grad CAM



Grad-CAM: Gradient-weighted Class Activation Mapping | Ramprasaath R. Selvaraju, Michael Cogswell, Abhishek Das, Ramakrishna Vedantam, Devi Parikh, Dhruv Batra

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Method #3: Grad CAM

```python
import cv2
import tensorflow as tf


IMAGE_PATH = "../img/cat.jpg"
TABBY_CAT_CLASS_INDEX = 281
NON_TABBY_CAT_CLASS_INDEX = 21  # Class "Kite"

# Load target image
img = tf.keras.preprocessing.image.load_img(IMAGE_PATH, target_size=(224, 224))
img = tf.keras.preprocessing.image.img_to_array(img)

# Load model
model = tf.keras.applications.vgg16.VGG16(weights="imagenet", include_top=True)

grad_cam_model = tf.keras.Model(
    [model.inputs], [model.get_layer("block5_conv3").output, model.output]
)

# Compute Gradients
with tf.GradientTape() as tape:
    inputs = tf.cast([img], tf.float32)
    conv_output, predictions = grad_cam_model(inputs)
    loss = predictions[:, NON_TABBY_CAT_CLASS_INDEX]

# Get Gradients
grads = tape.gradient(loss, conv_output)[0]

# Compute Class Activation Maps
weights = tf.reduce_sum(grads, axis=(0, 1))
gradcam = tf.reduce_sum(tf.multiply(weights, conv_output), axis=-1)[0].numpy()
```

Create subgraph to also extract convolutional outputs

Get gradients for target class

Compute gradients

Ponderate Class Activation Maps

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Method #3: Grad CAM

Input image

GradCAM for
“Cat” class

GradCAM for
“Kite” class

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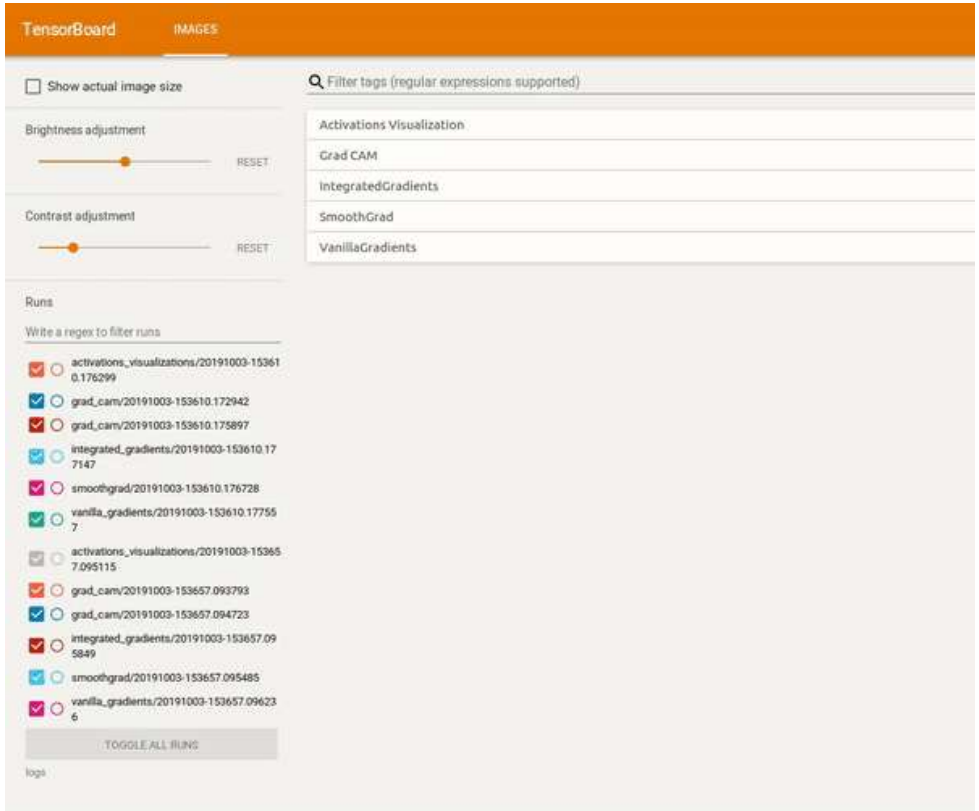
tf-explain

tf-explain
An interpretability library for TF2.0



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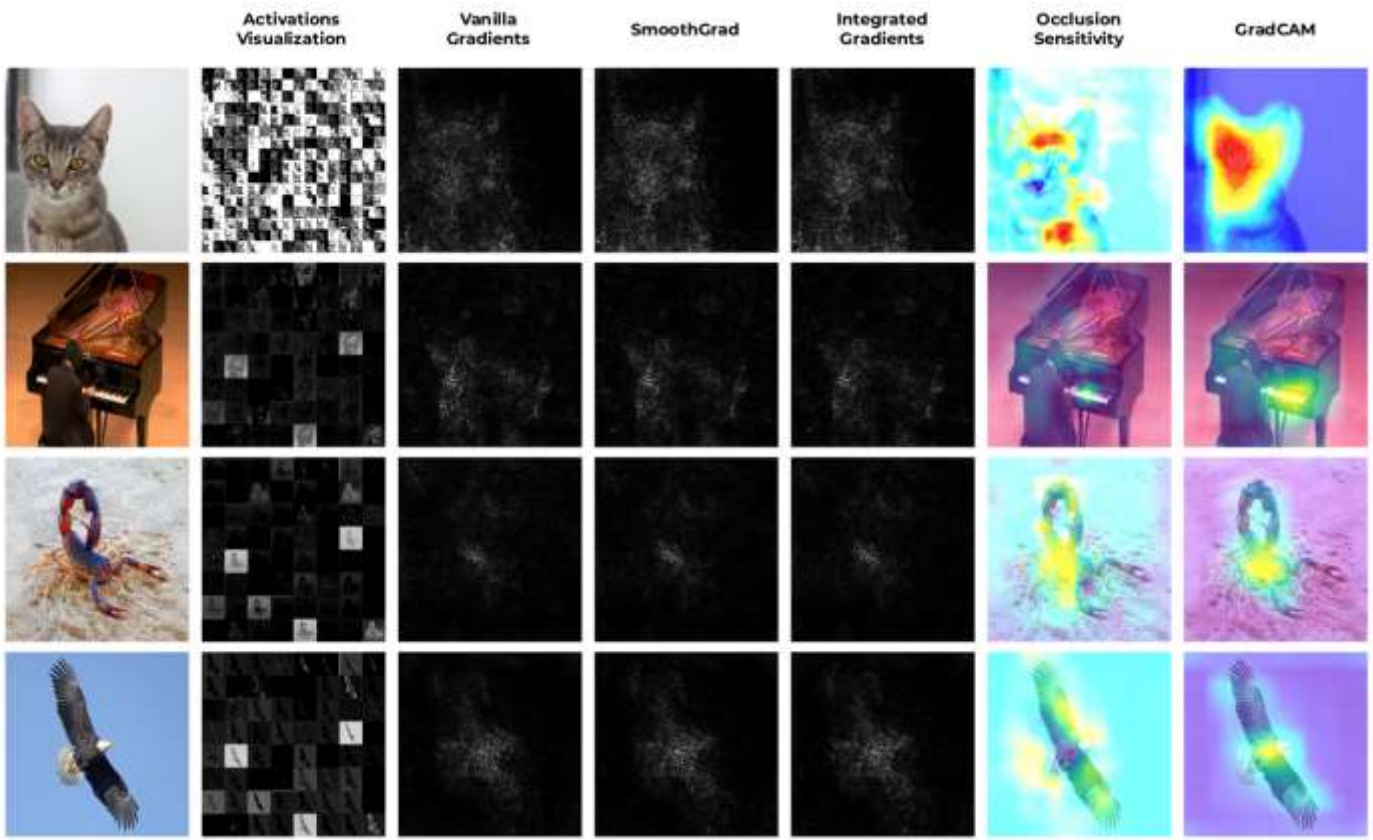
Methods implemented



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Uses
tf_explain.core

```python
import tensorflow as tf

from tf_explain.core.grad_cam import GradCAM

IMAGE_PATH = './cat.jpg'

model = tf.keras.applications.vgg16.VGG16(weights='imagenet', include_top=True)

img = tf.keras.preprocessing.image.load_img(IMAGE_PATH, target_size=(224, 224))
img = tf.keras.preprocessing.image.img_to_array(img)

model.summary()
data = ([img], None)

tabby_cat_class_index = 281

explainer = GradCAM()
grid = explainer.explain(data, model, 'block5_conv3', tabby_cat_class_index)
explainer.save(grid, '.', 'grad_cam.png')
```

Load model and validation data

Instantiate explainer
Call .explain() method

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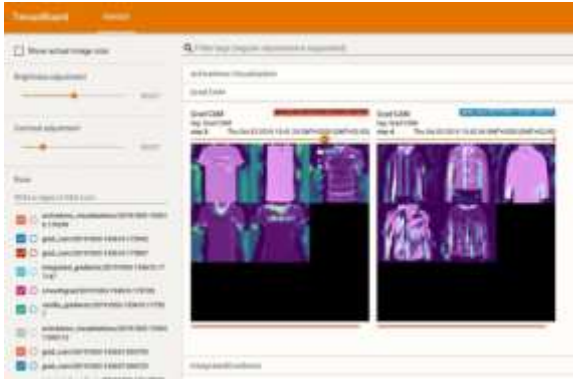
Uses
tf_explain.callbacks

```python
import numpy as np
import tensorflow as tf
import tf_explain

INPUT_SHAPE = (28, 28, 1)
NUM_CLASSES = 10

(train_images, train_labels), (test_images, test_labels) = tf.keras.datasets.mnist.load_data()

model = ...

# Select a subset of the validation data to examine
# Here, we choose 5 elements with label "0" == [1, 0, 0, ..., 0]
validation_class_zero = (np.array([
    el for el, label in zip(test_images, test_labels)
    if np.all(label == np.array([1] + [0] * 9))
][0:5]), None)

# Instantiate callbacks
# class_index value should match the validation_data selected above
callbacks = [tf_explain.callbacks.GradCAMCallback(validation_class_zero, 'target_layer', class_index=0)]

# Start training
model.fit(train_images, train_labels, epochs=5, callbacks=callbacks)
```



Load dataset of a specific class index

Create callback

Call .fit() with callback

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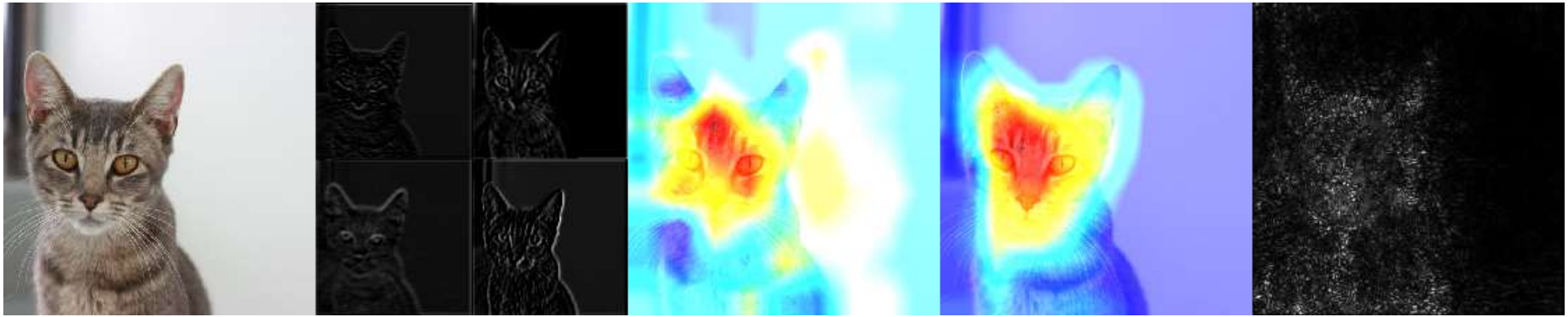
Available on PyPi



```
>> pip install tf-explain
```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Github: **github.com/sicara/tf-explain**

Twitter: **@cpierrehenri / @raphaelmeudec**

Thank you