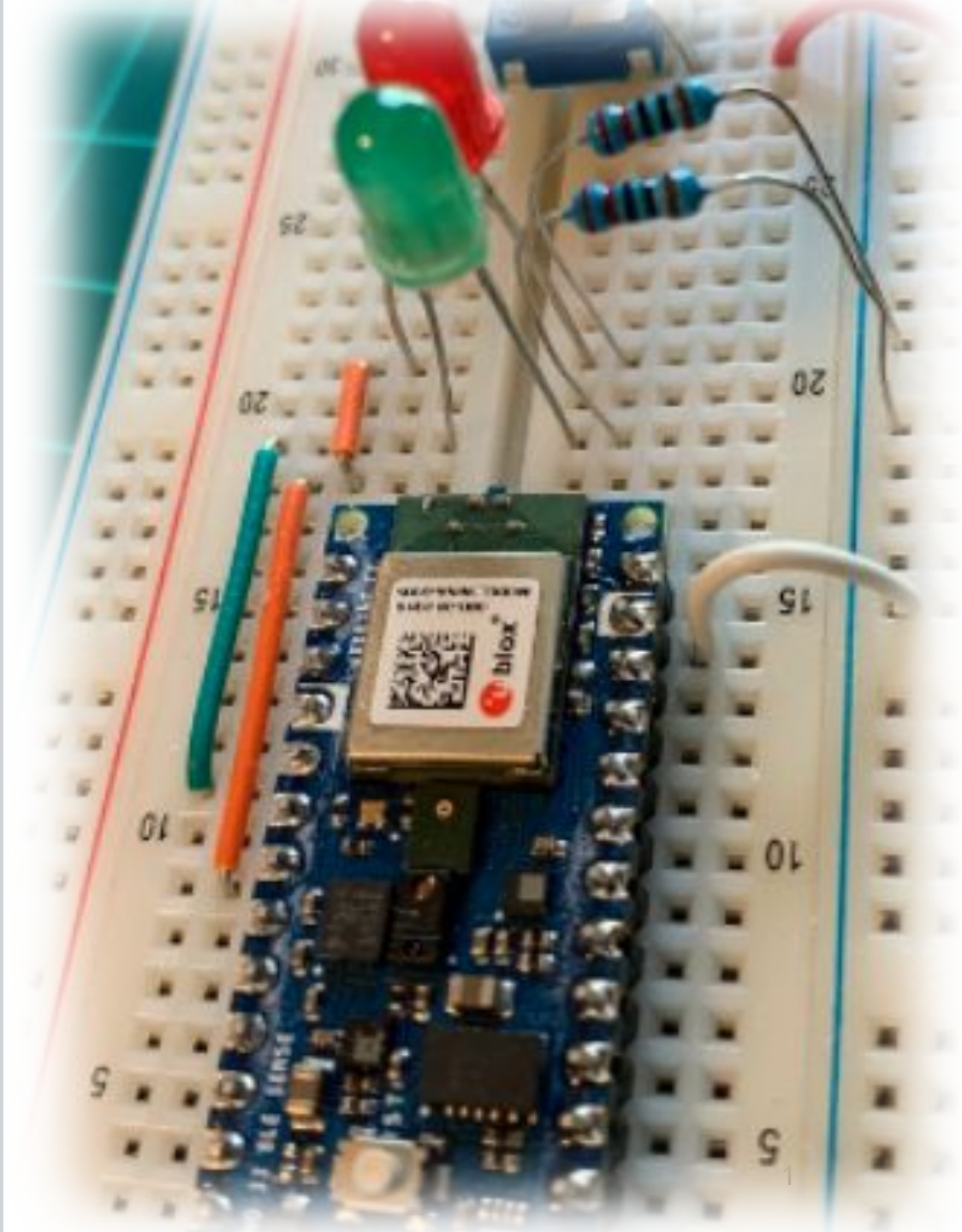
IESTI01 – TinyML

Embedded Machine Learning

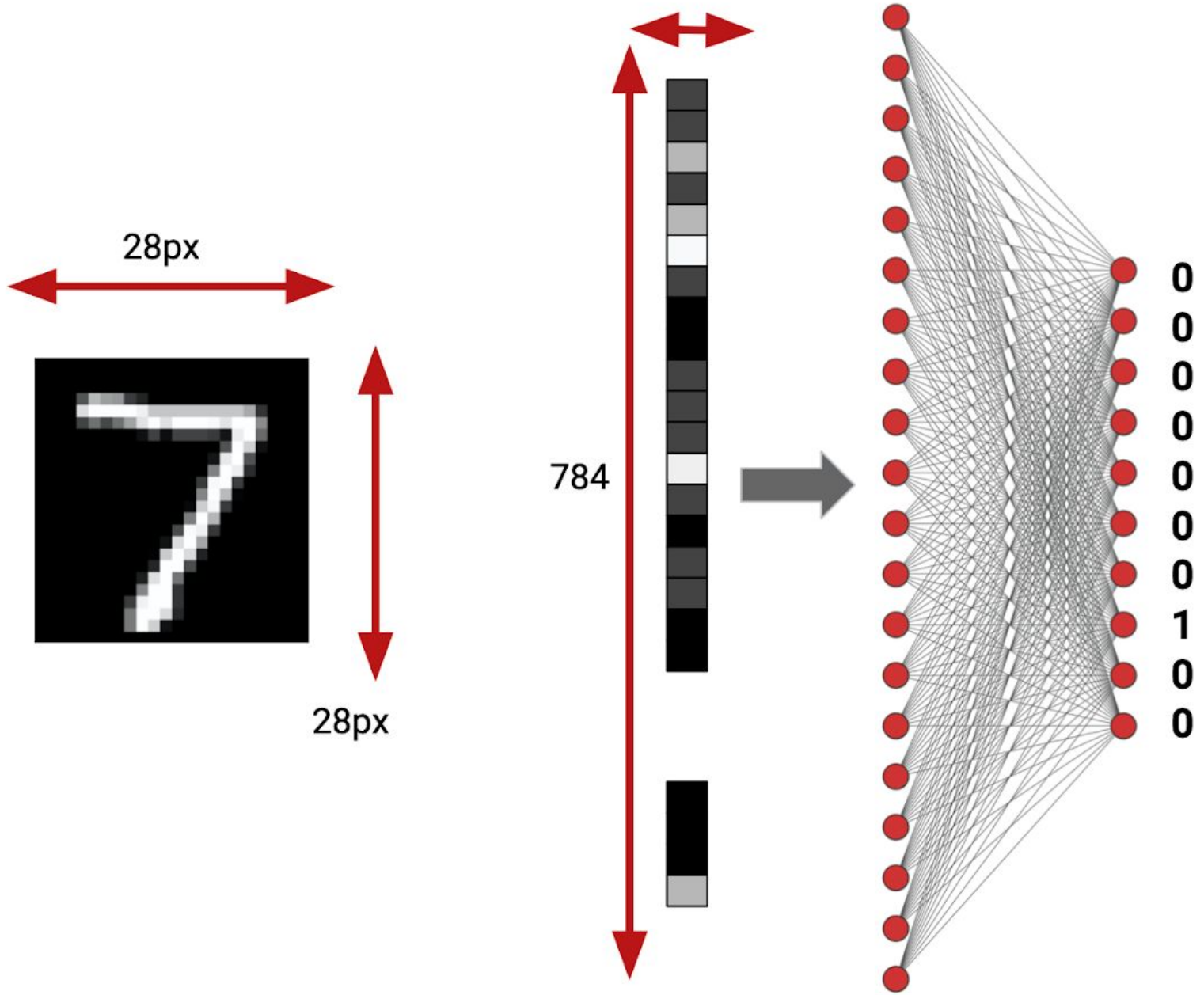
10. Introducing Convolutions



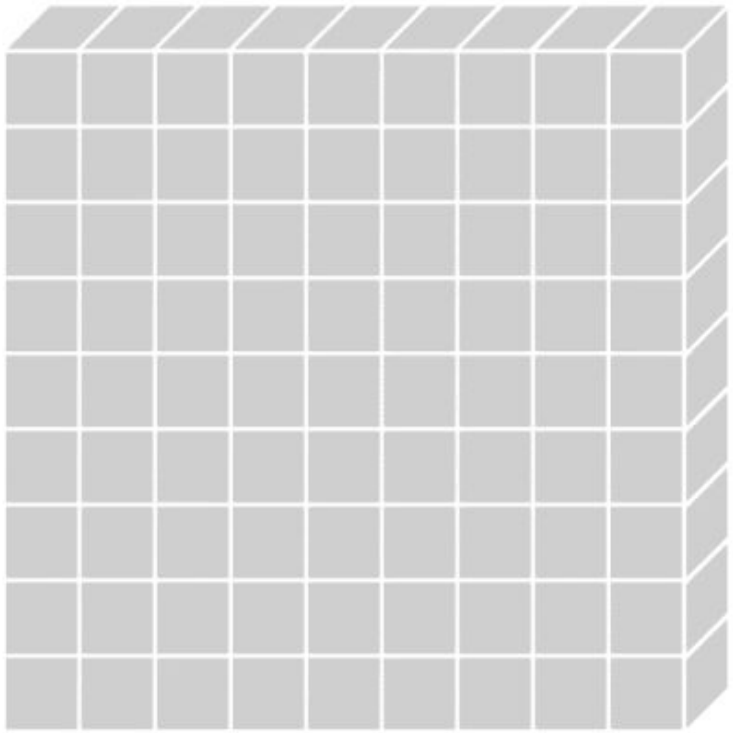
Prof. Marcelo Rovai
UNIFEI

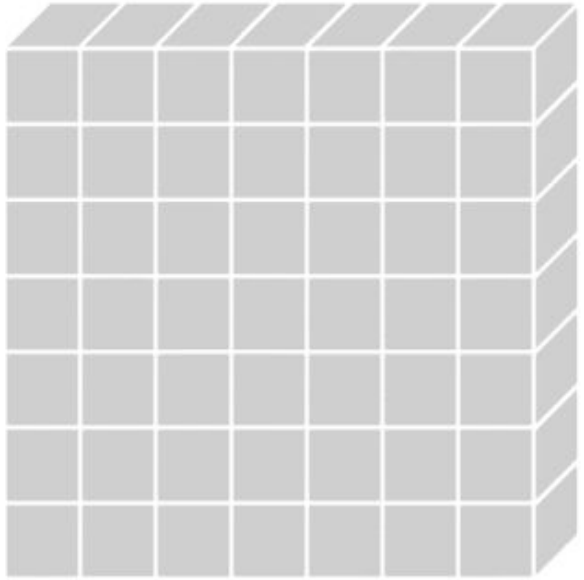
Introducing Convolutions

Beyond weights and biases…

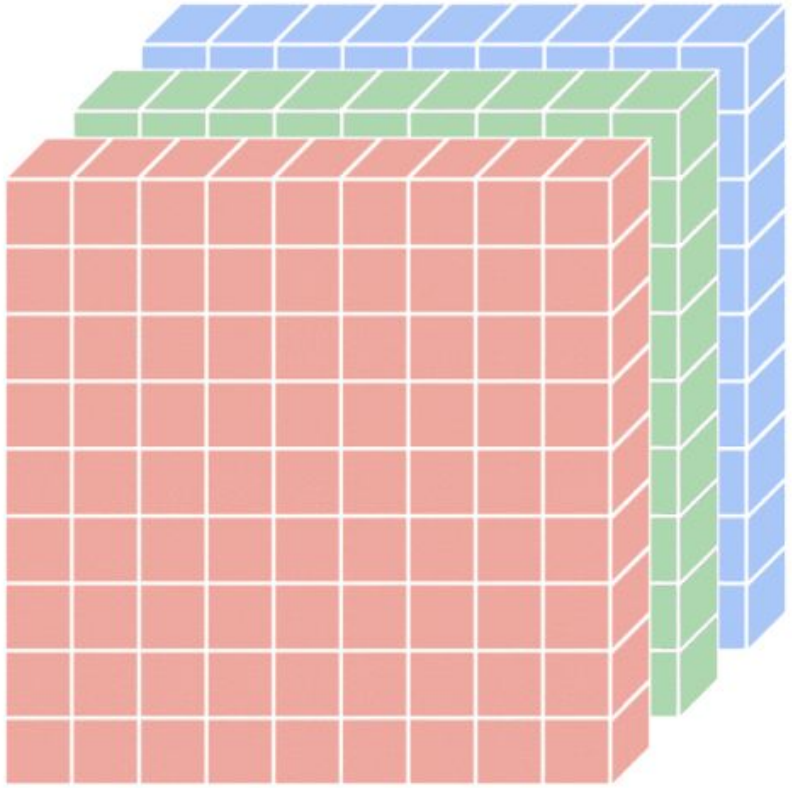

28px
28px
784
0
0
0
0
0
0
0
1
0
0

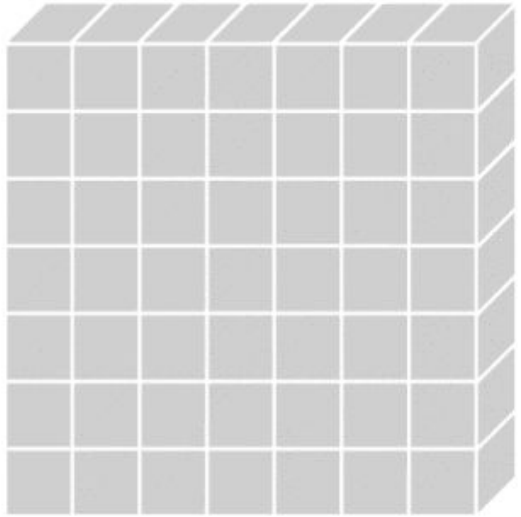
Standard Convolution (1 Channel)





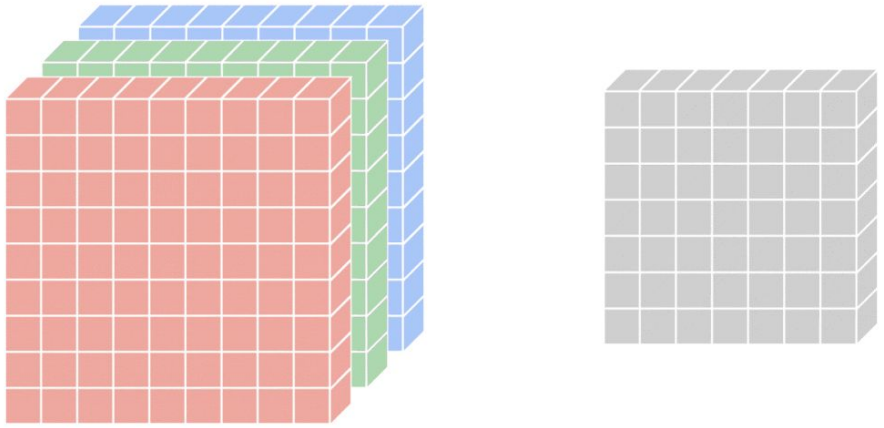
Standard Convolution ***(3 Channel**—e.g., RGB)*

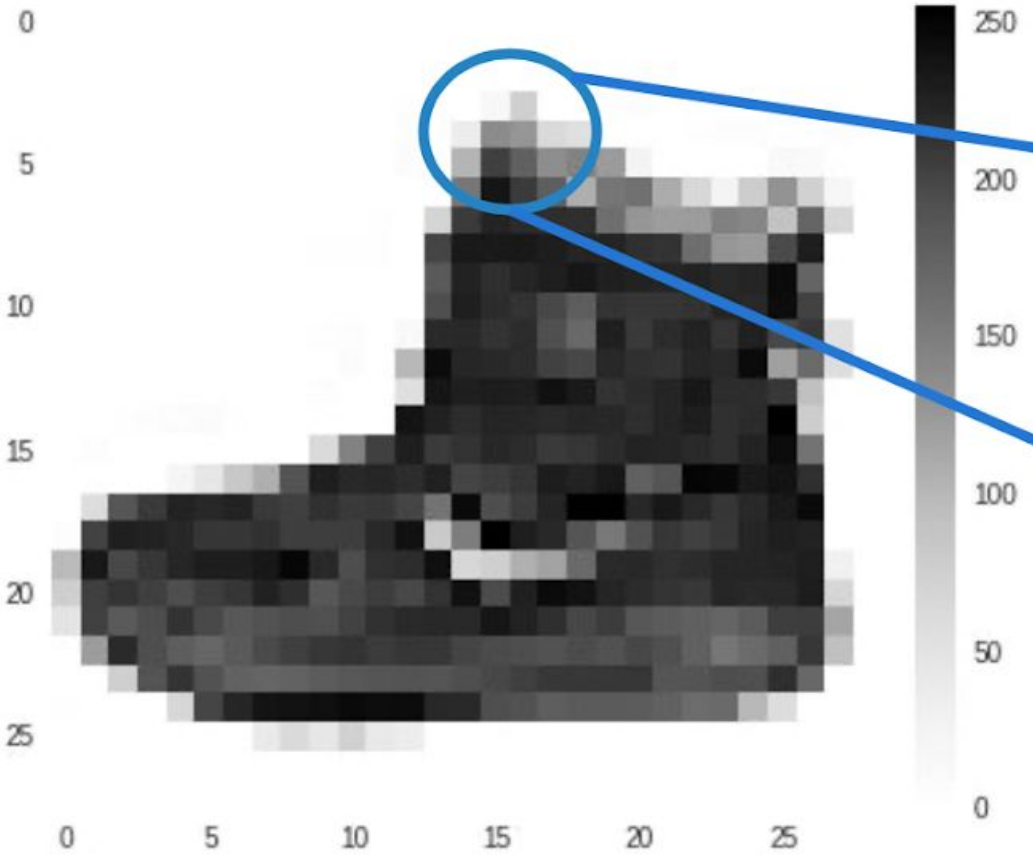




Standard Convolution ***(3 Channel**—e.g., RGB)*

- Input Feature Map
  - 8 × 8 × 3
  - Width × Height × Channels
- Kernel (*1 Filter*)
  - 3 × 3 × 3





0	64	128
48	192	144
142	226	168

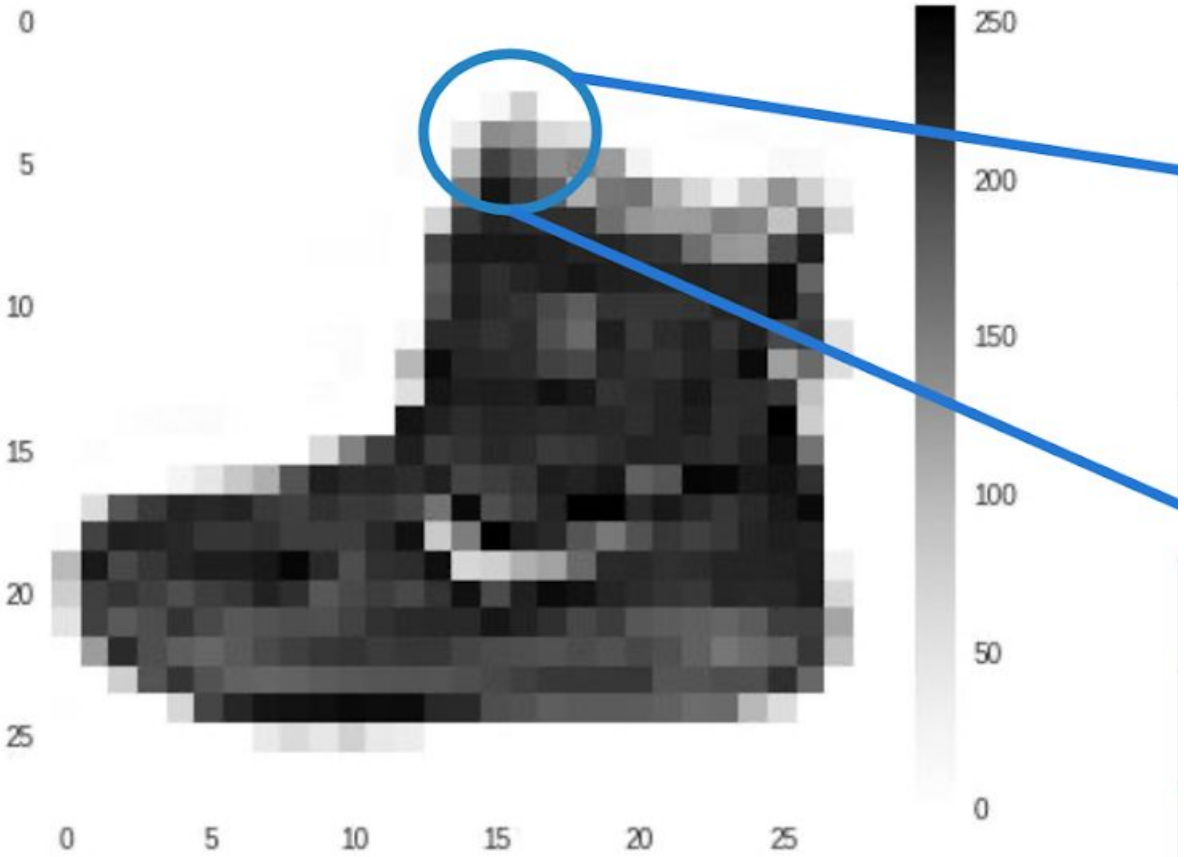
Current Pixel Value is 192

Consider neighbor Values

-1	0	-2
.5	4.5	-1.5
1.5	2	-3

Filter Definition

```
CURRENT_PIXEL_VALUE = 192
NEW_PIXEL_VALUE = (-1 * 0) + (0 * 64) + (-2 * 128) +
                  (.5 * 48) + (4.5 * 192) + (-1.5 * 144) +
                  (1.5 * 42) + (2 * 226) + (-3 * 168)
```



Kernels = Filters

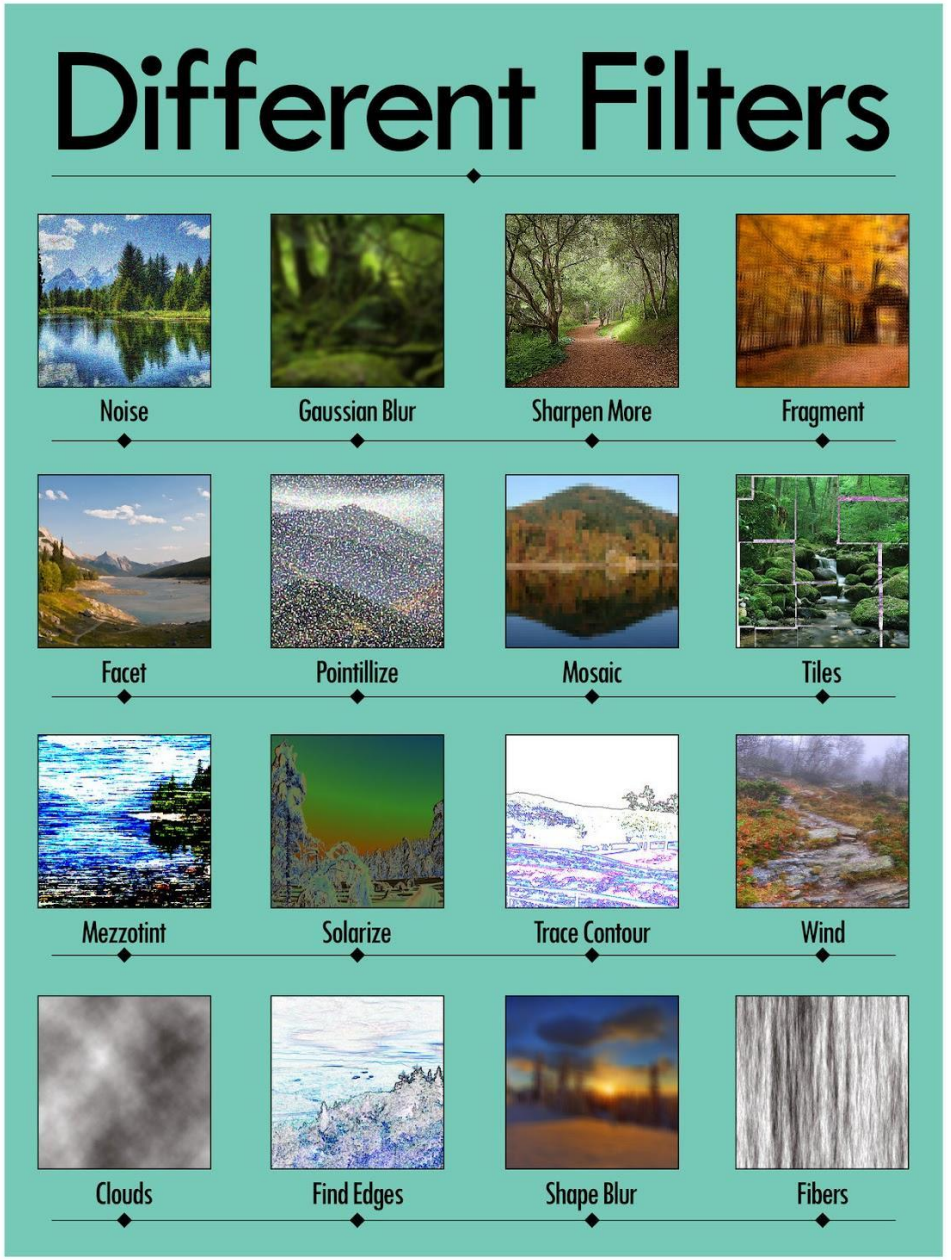


Image Kernels

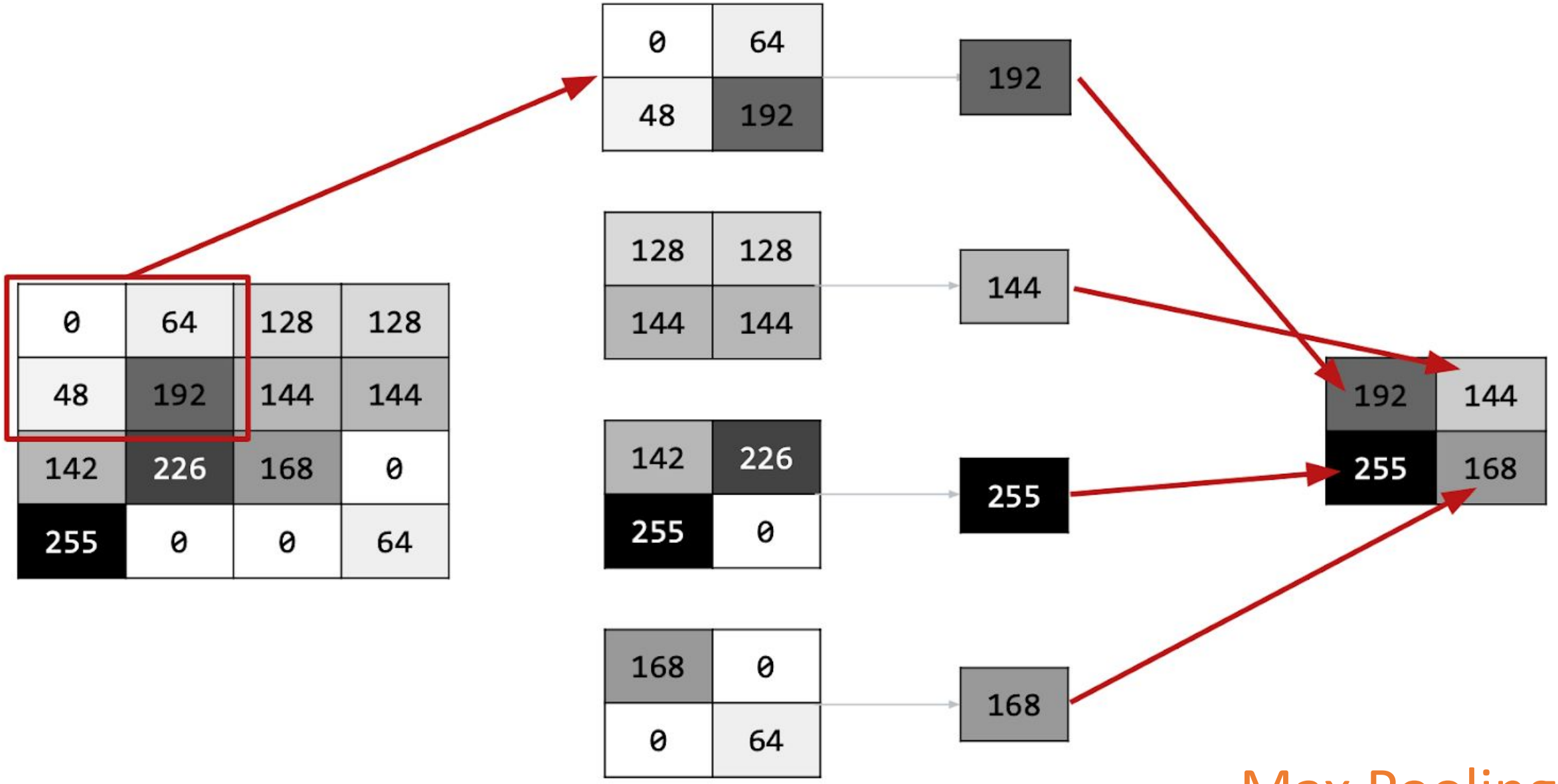
-1	0	1
-2	0	2
-1	0	1

custom

-1	-2	-1
0	0	0
1	2	1

custom

https://setosa.io/ev/image-kernels/


0 64 128 128
48 192 144 144
142 226 168 0
255 0 0 64
0 64
48 192
128 128
144 144
142 226
255 0
168 0
0 64
192
144
255
168
192 144
255 168

Max Pooling

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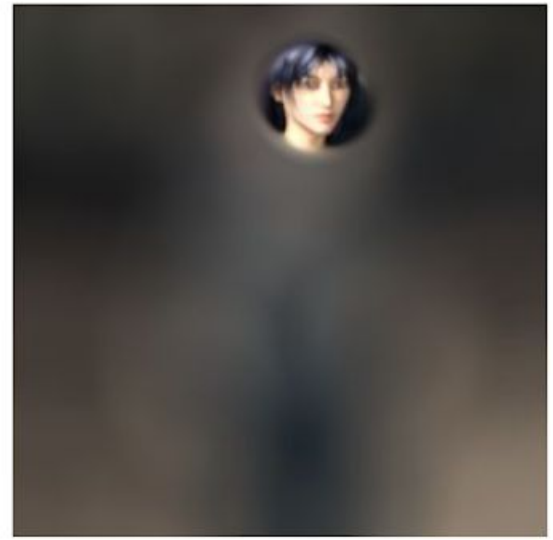

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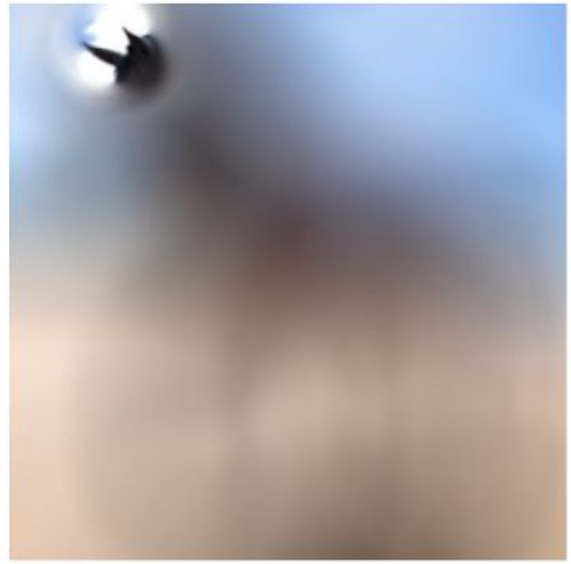

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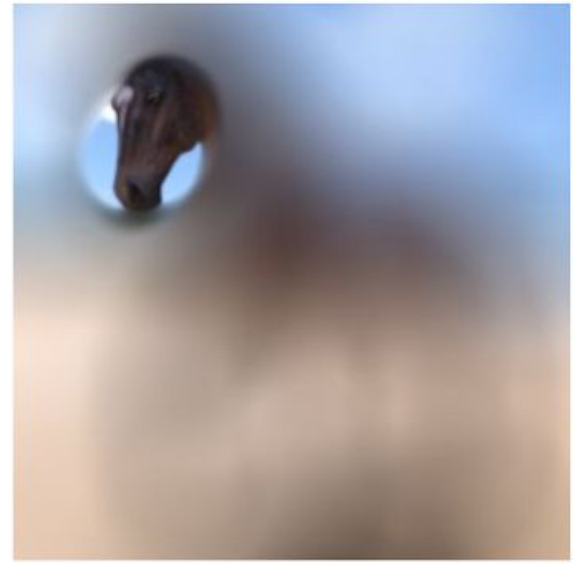

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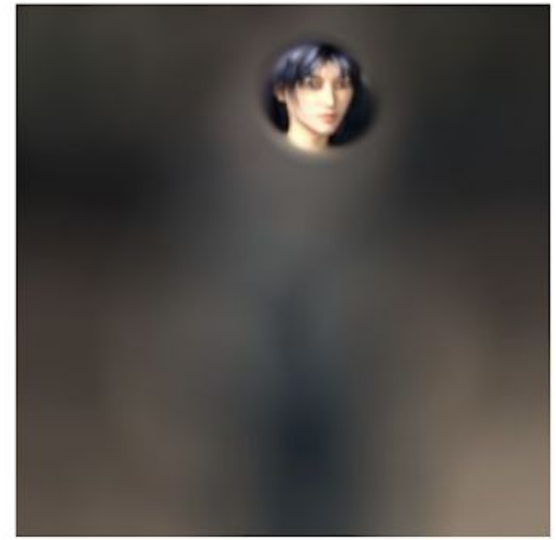

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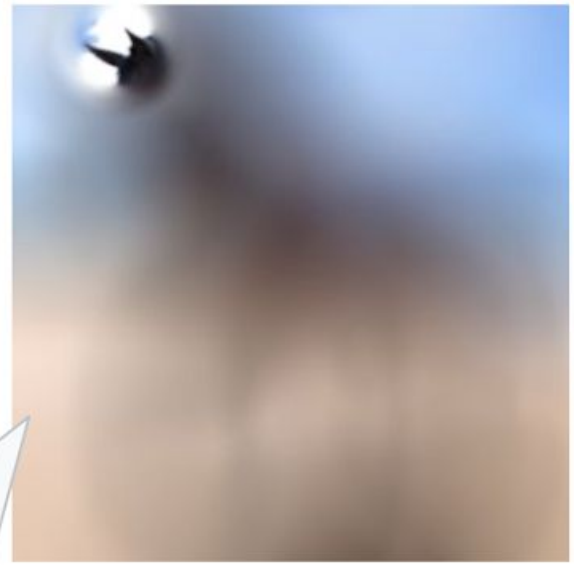

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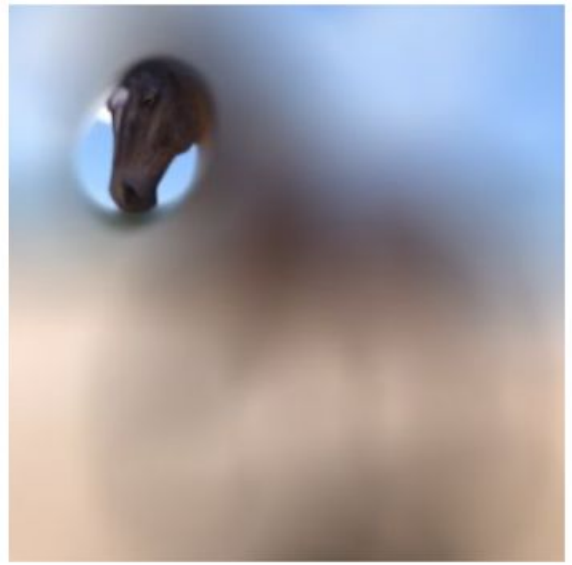

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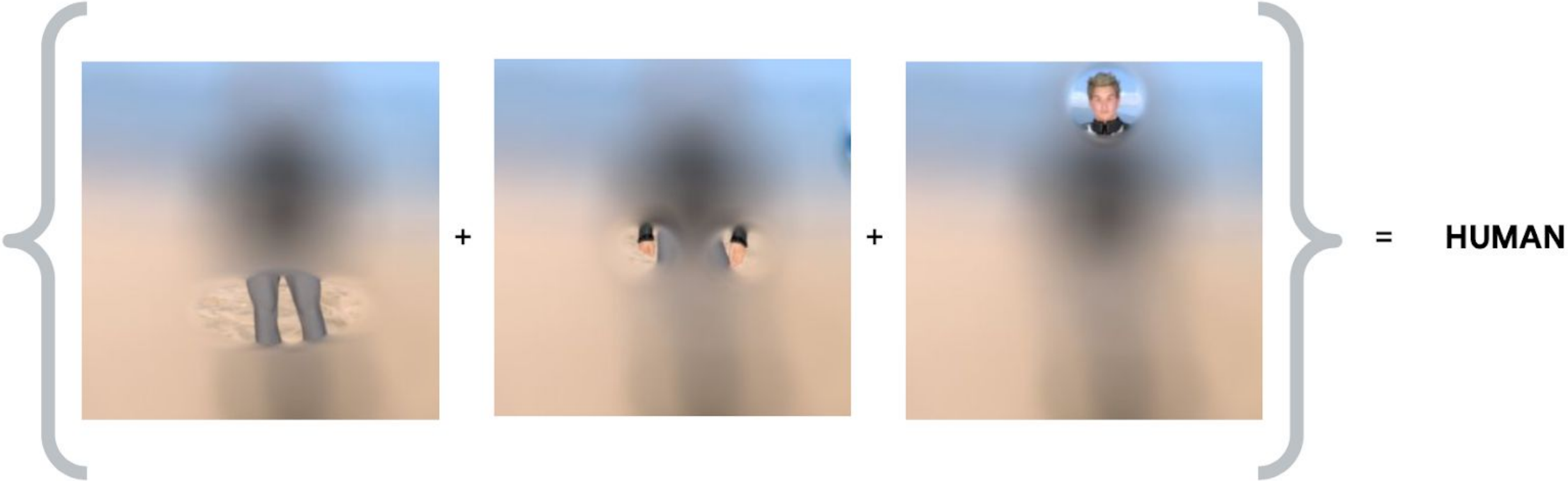
Filters can then be combined with **labels** to make a **prediction** of the image contents...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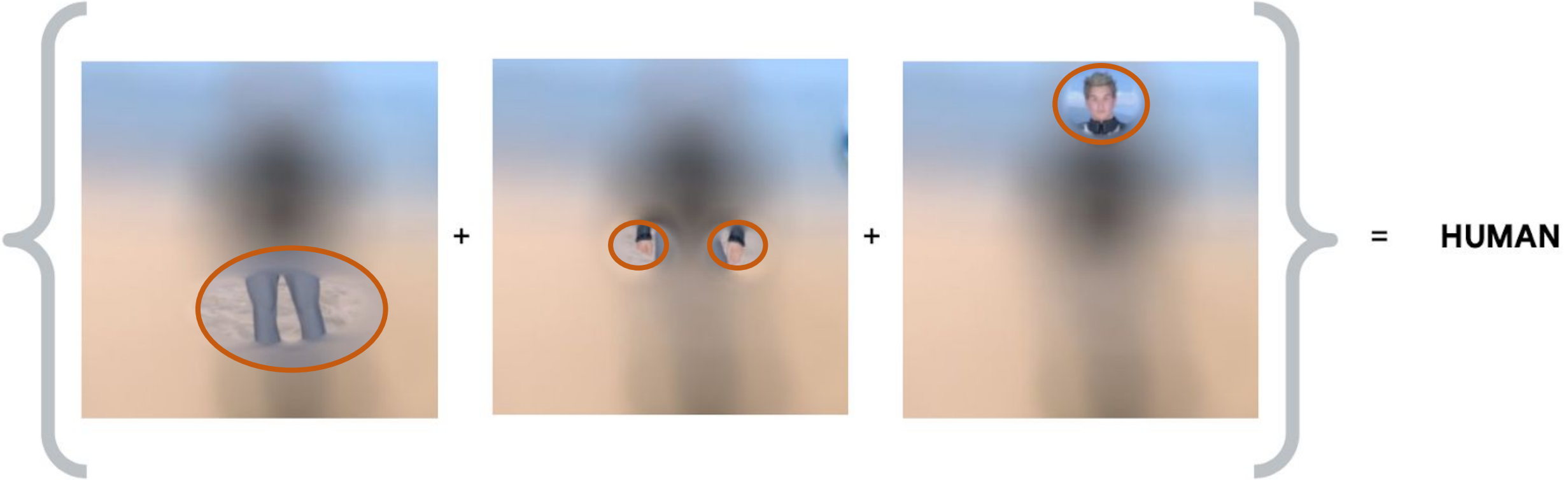

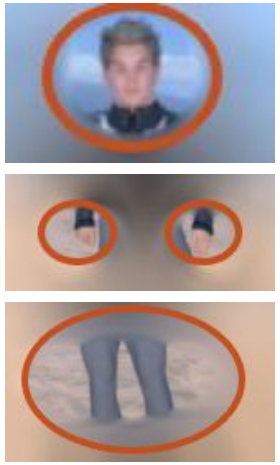

Data

Model

Inferences

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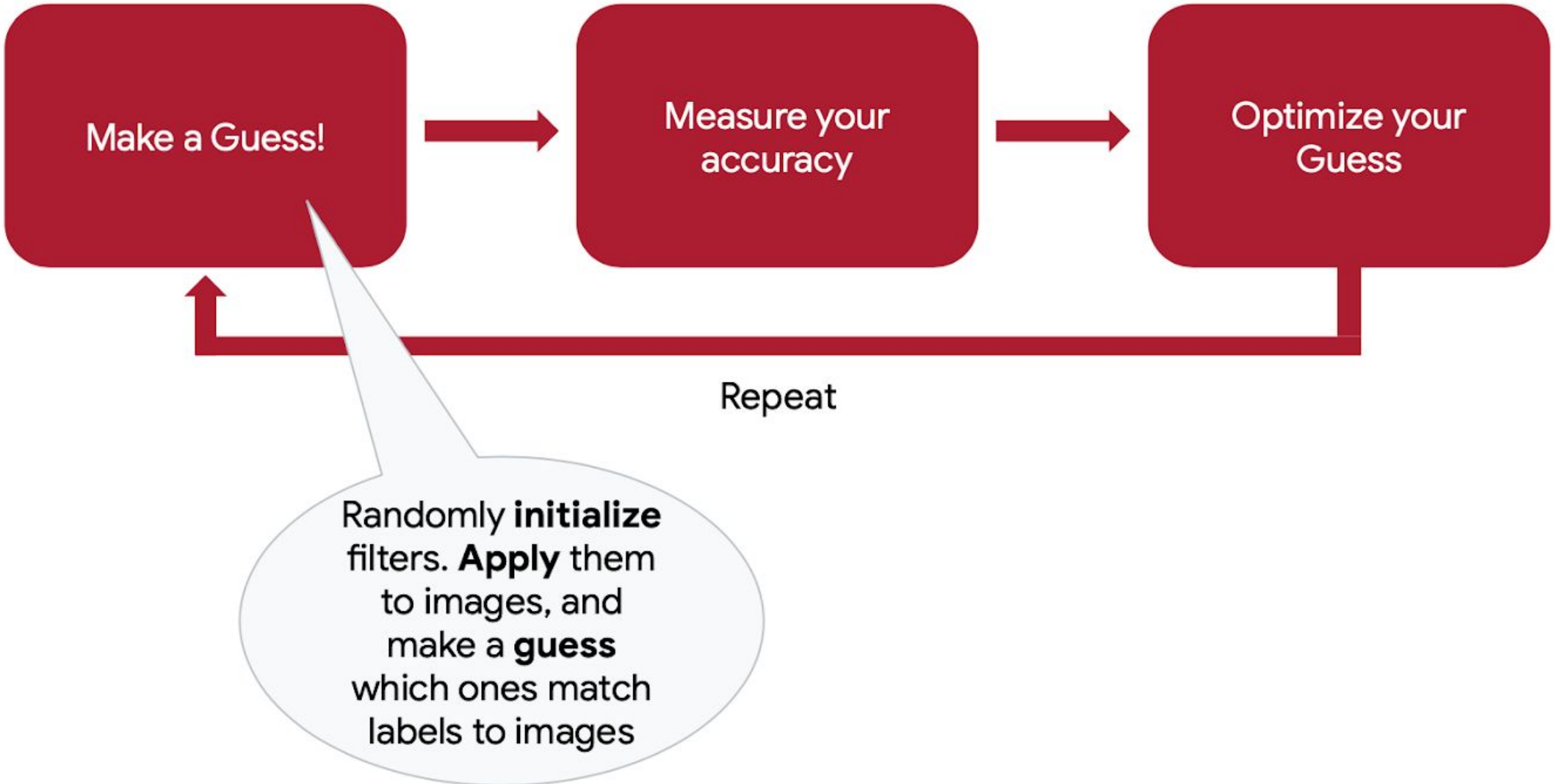
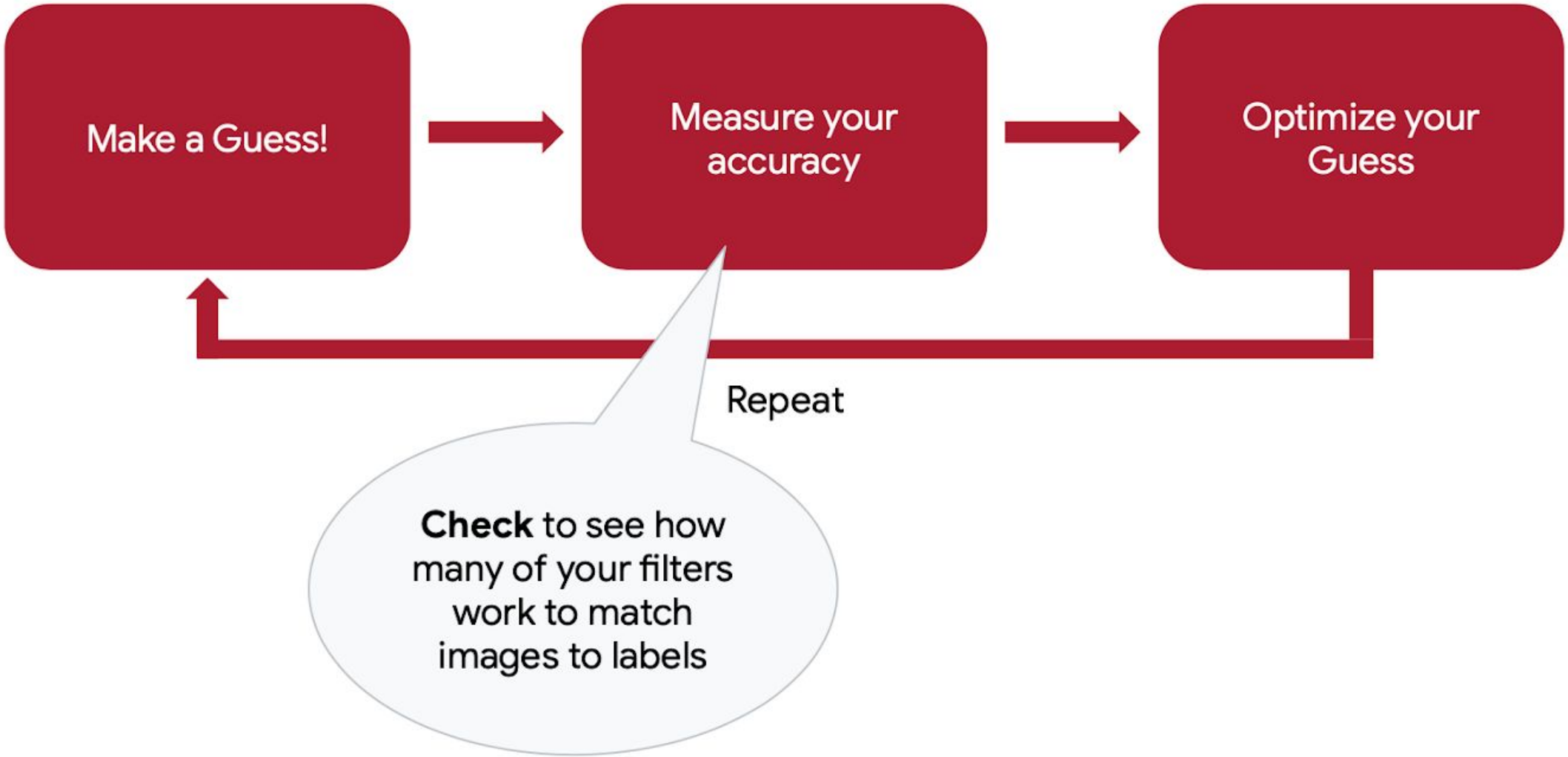
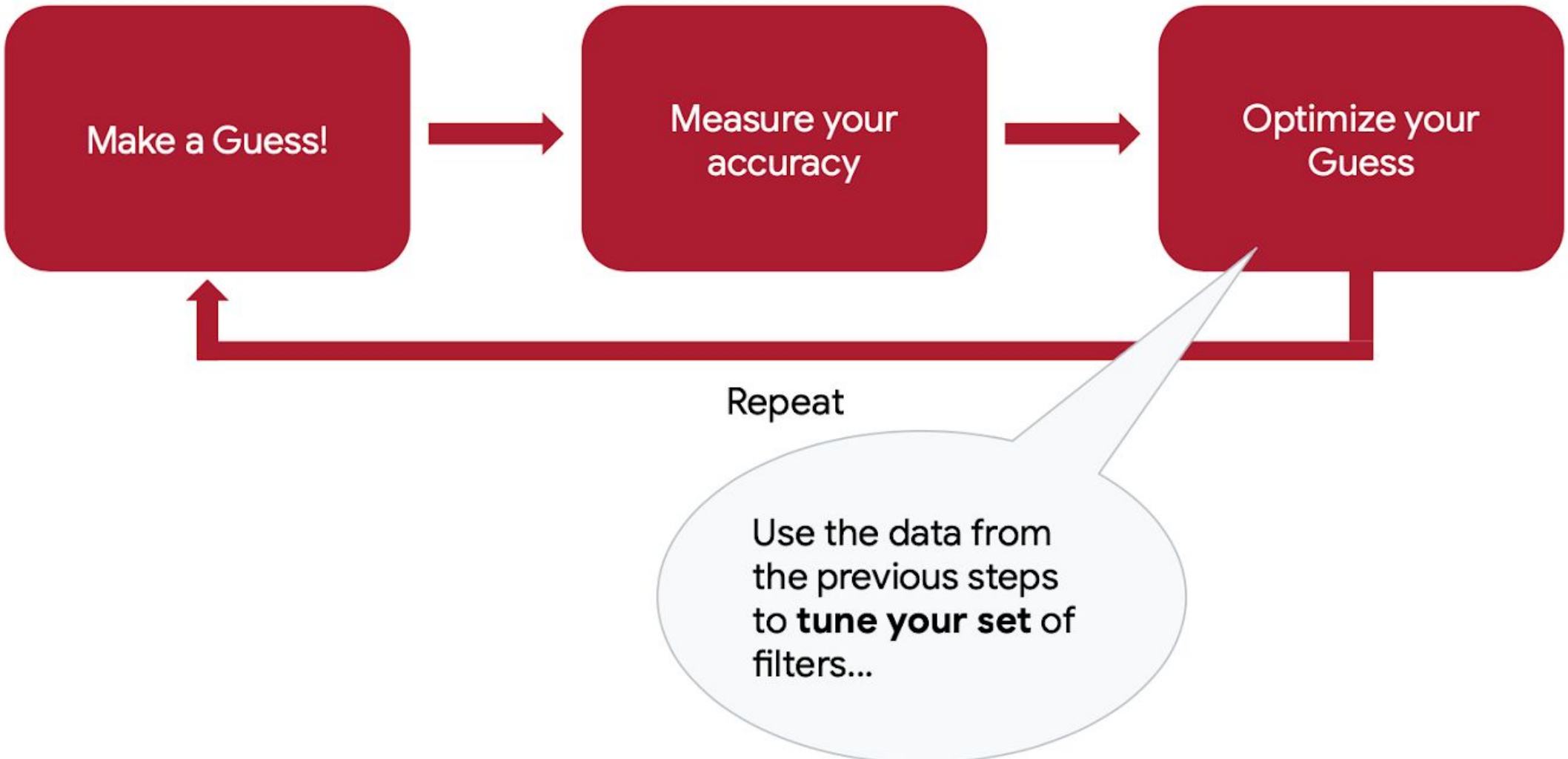
The Machine Learning Paradigm



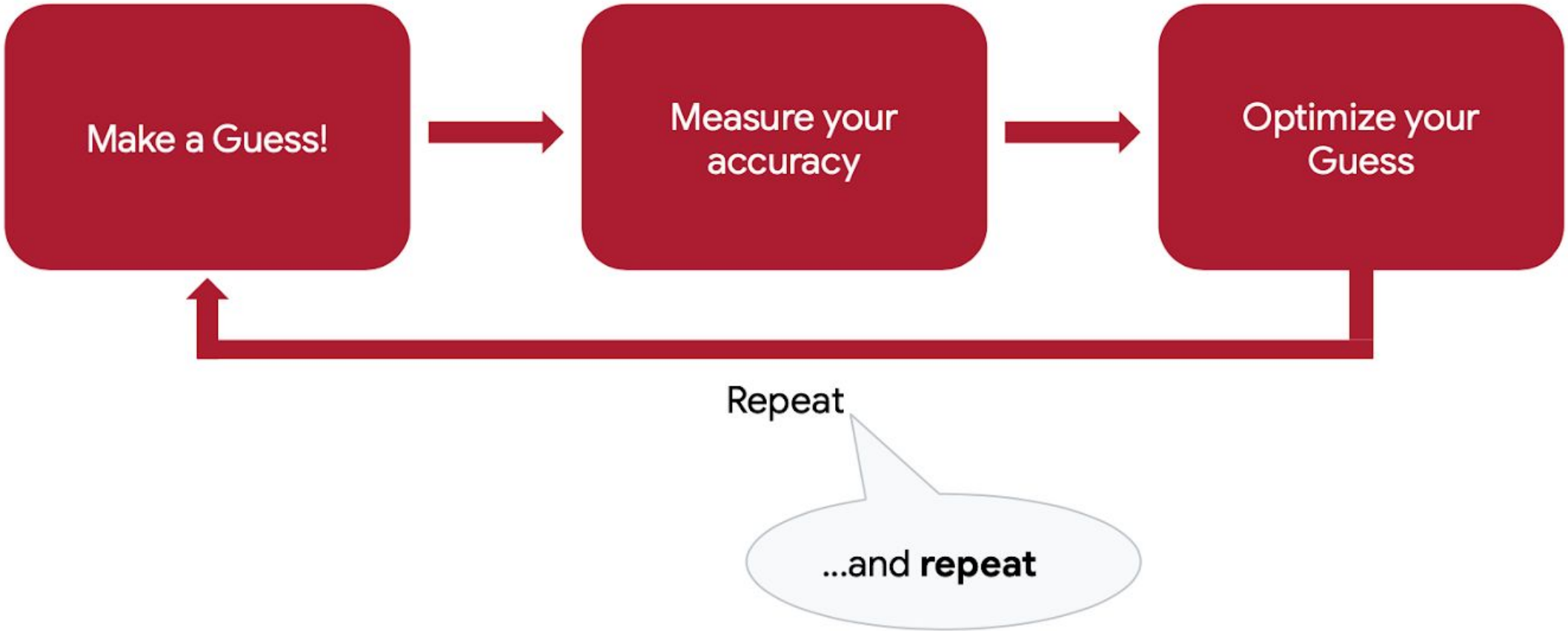
The Machine Learning Paradigm



The Machine Learning Paradigm



The Machine Learning Paradigm



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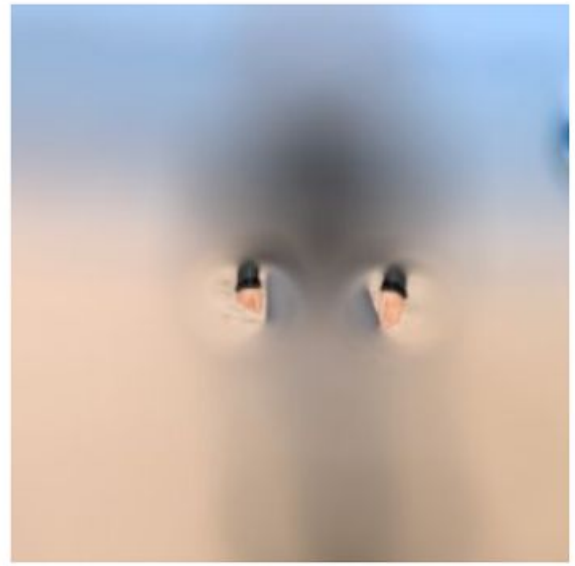

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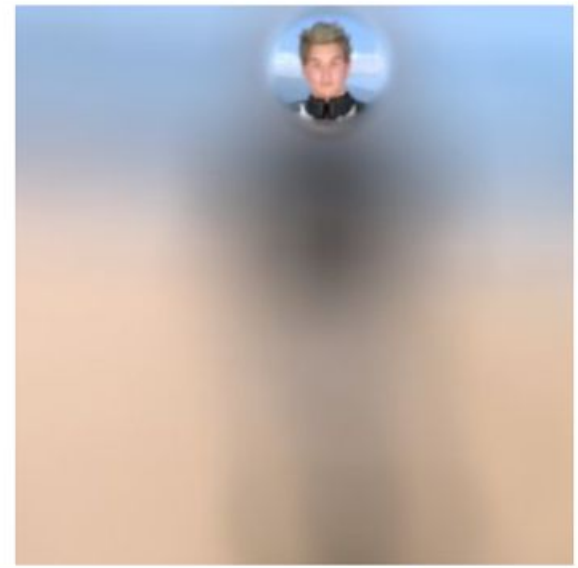

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Exploring CNN

CNN Explainer

https://poloclub.github.io/cnn-explainer/

ConvNetJS MNIST demo

https://cs.stanford.edu/people/karpathy/convnetjs/demo/mnist.html

ConvNetJS CIFAR-10 demo

https://cs.stanford.edu/people/karpathy/convnetjs/demo/cifar10.html

Reading Material

Main references

- Harvard School of Engineering and Applied Sciences - CS249r: Tiny Machine Learning
- Professional Certificate in Tiny Machine Learning (TinyML) – edX/Harvard
- Introduction to Embedded Machine Learning - Coursera/Edge Impulse
- Computer Vision with Embedded Machine Learning - Coursera/Edge Impulse
- Fundamentals textbook: “Deep Learning with Python” by François Chollet
- Applications & Deploy textbook: “TinyML” by Pete Warden, Daniel Situnayake
- Deploy textbook “TinyML Cookbook” by Gian Marco Iodice

I want to thank Shawn Hymel and Edge Impulse, Pete Warden and Laurence Moroney from Google, Professor Vijay Janapa Reddi and Brian Plancher from Harvard, and the rest of the TinyMLedu team for preparing the excellent material on TinyML that is the basis of this course at UNIFEI.

The IESTI01 course is part of the **TinyML4D**, an initiative to make TinyML education available to everyone globally.

Thanks

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