
FOUNDATIONS OF FACIAL RECOGNITION

Daniel Hinojosa

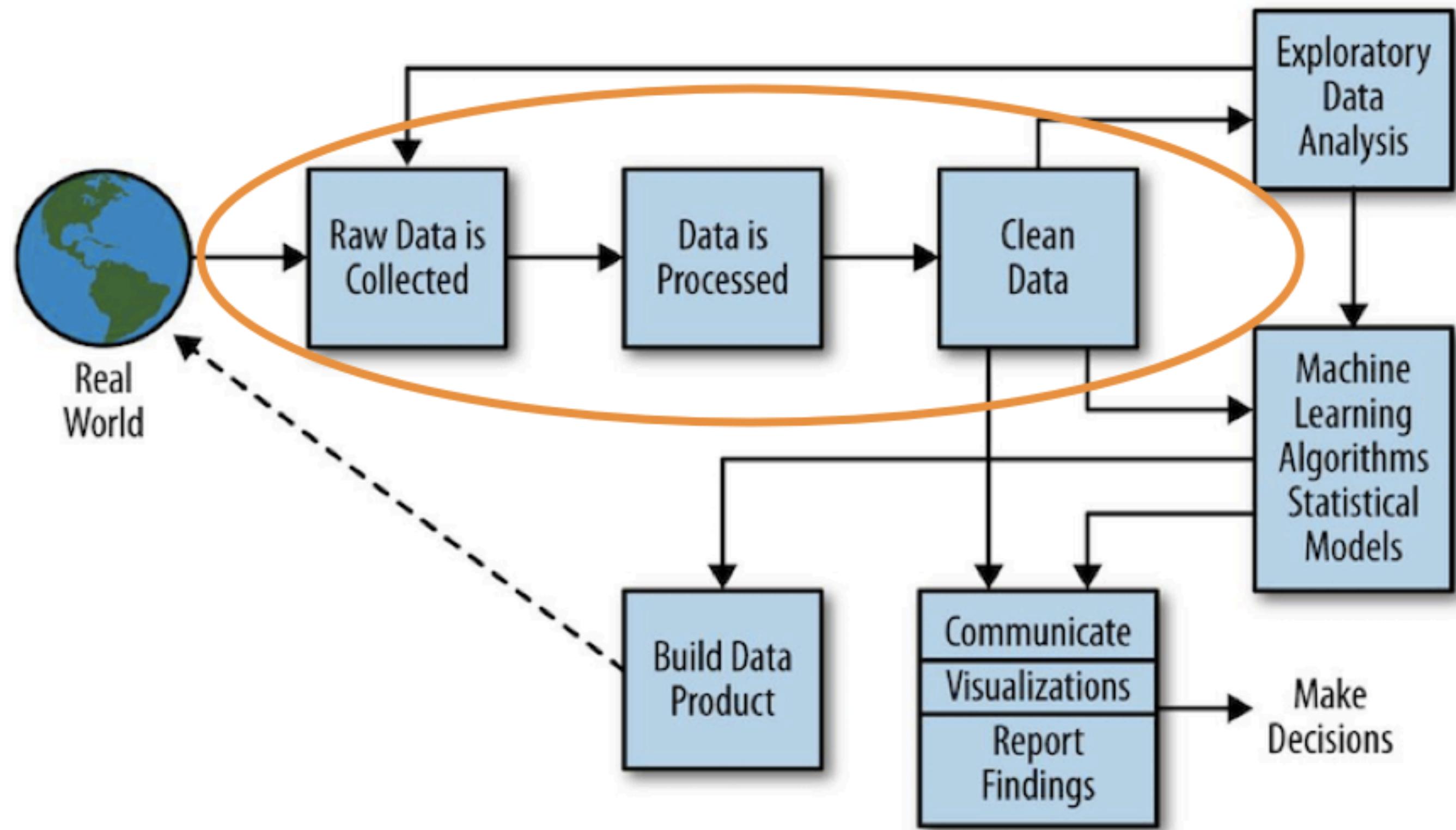
PRESENTATION AND CODE

<https://github.com/dhinojosa/foundation-facial-recognition>

FACIAL DETECTION & RECOGNITION

- **Facial Detection**
 - **Detecting face in an image**
 - **Facial Recognition**
 - **Using algorithms to identify who the face belongs to**
 - **A form of person identification**
-

PROCESS OF MACHINE LEARNING



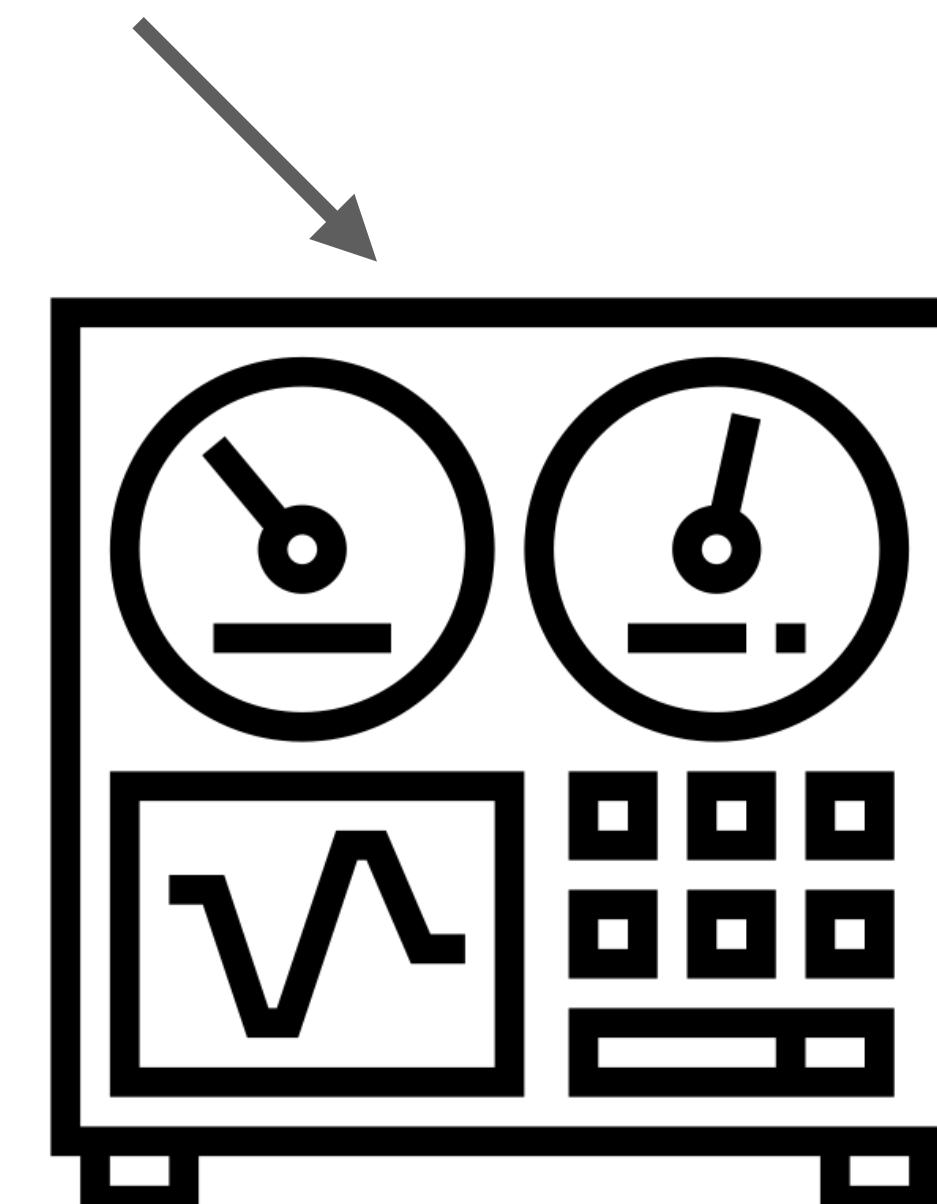
training

0	63	1	233	1
1	37	1	250	0
2	41	0	204	1
3	56	1	236	1
4	57	0	354	0
5	57	1	192	0
6	56	0	294	0
7	44	1	263	1
8	52	1	199	1
9	57	1	168	1

testing

10	54	1	239	1
11	48	0	275	0
12	49	1	266	1
13	64	1	211	0
14	58	0	283	1

training phase



id	age	sex	trestbps	risk
0	20	1	145	1
1	45	1	130	1
2	43	0	130	0
3	33	1	150	0

data

target

training →

testing ↗

id	age	sex	trestbps	target
0	63	1	233	1
1	37	1	250	0
2	41	0	204	1
3	56	1	236	1
4	57	0	354	0
5	57	1	192	0
6	56	0	294	0
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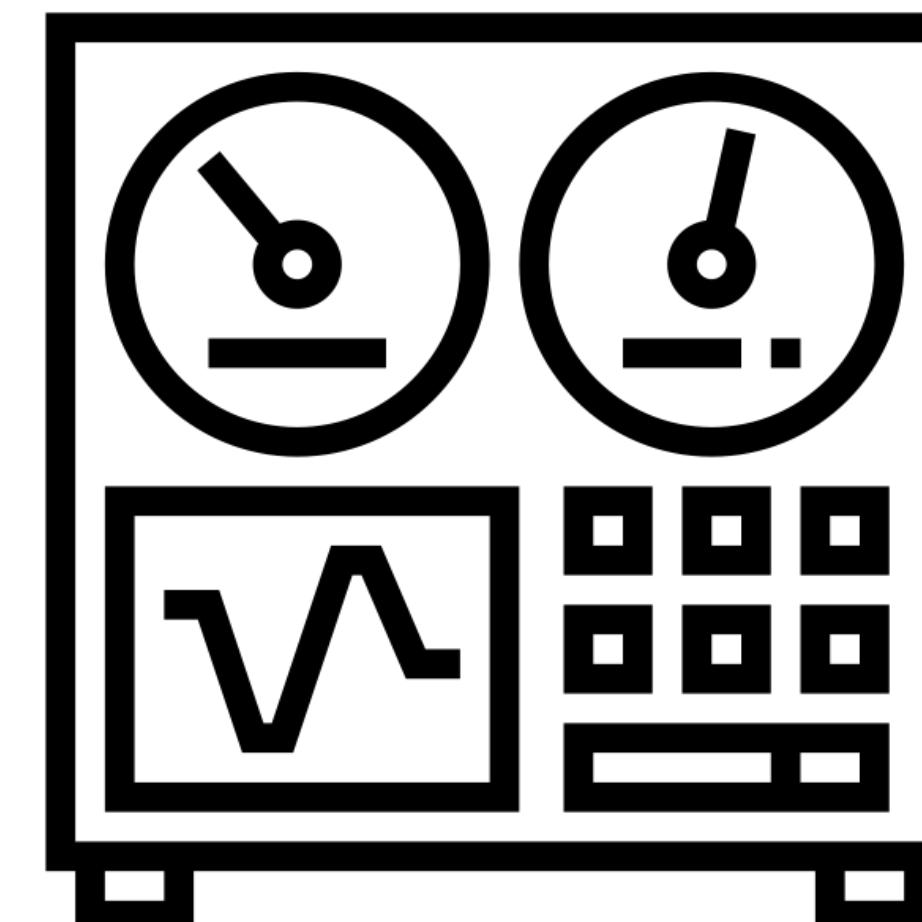
random distribution between training and testing

training

0	63	1	233	1
1	37	1	250	0
2	41	0	204	1
3	56	1	236	1
4	57	0	354	0
5	57	1	192	0
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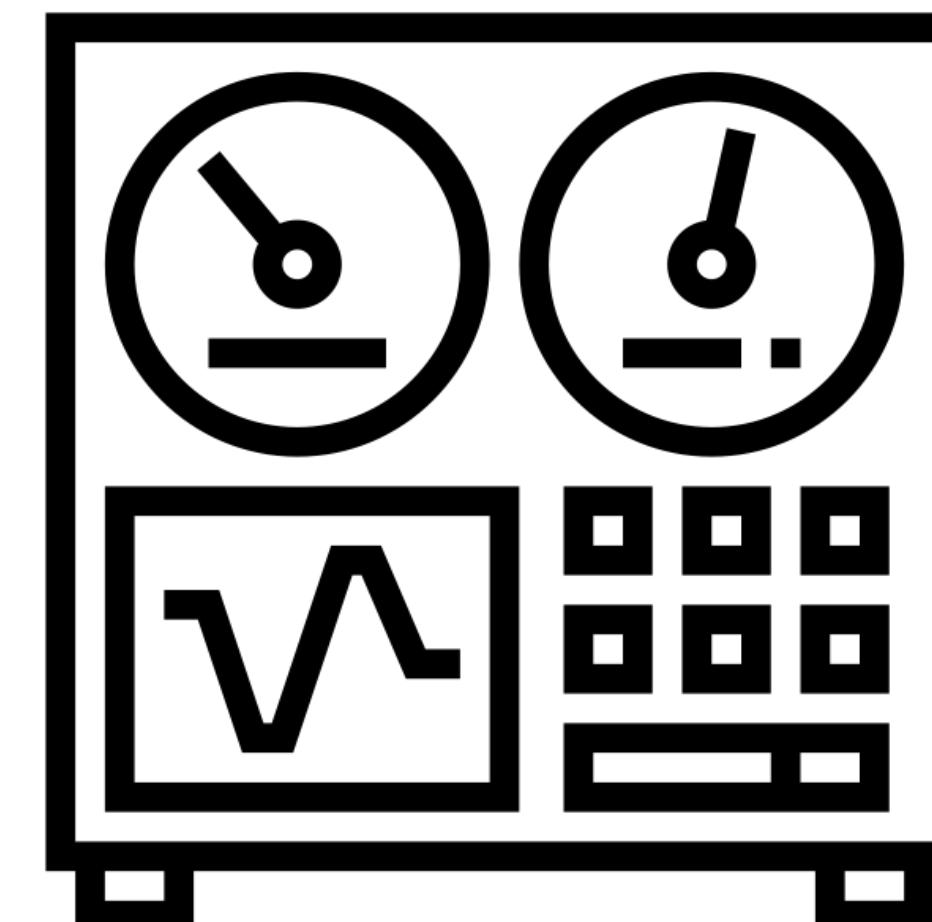
training

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1	37	1	250	0
2	41	0	204	1
3	56	1	236	1
4	57	0	354	0
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testing

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14	58	0	283	1

model



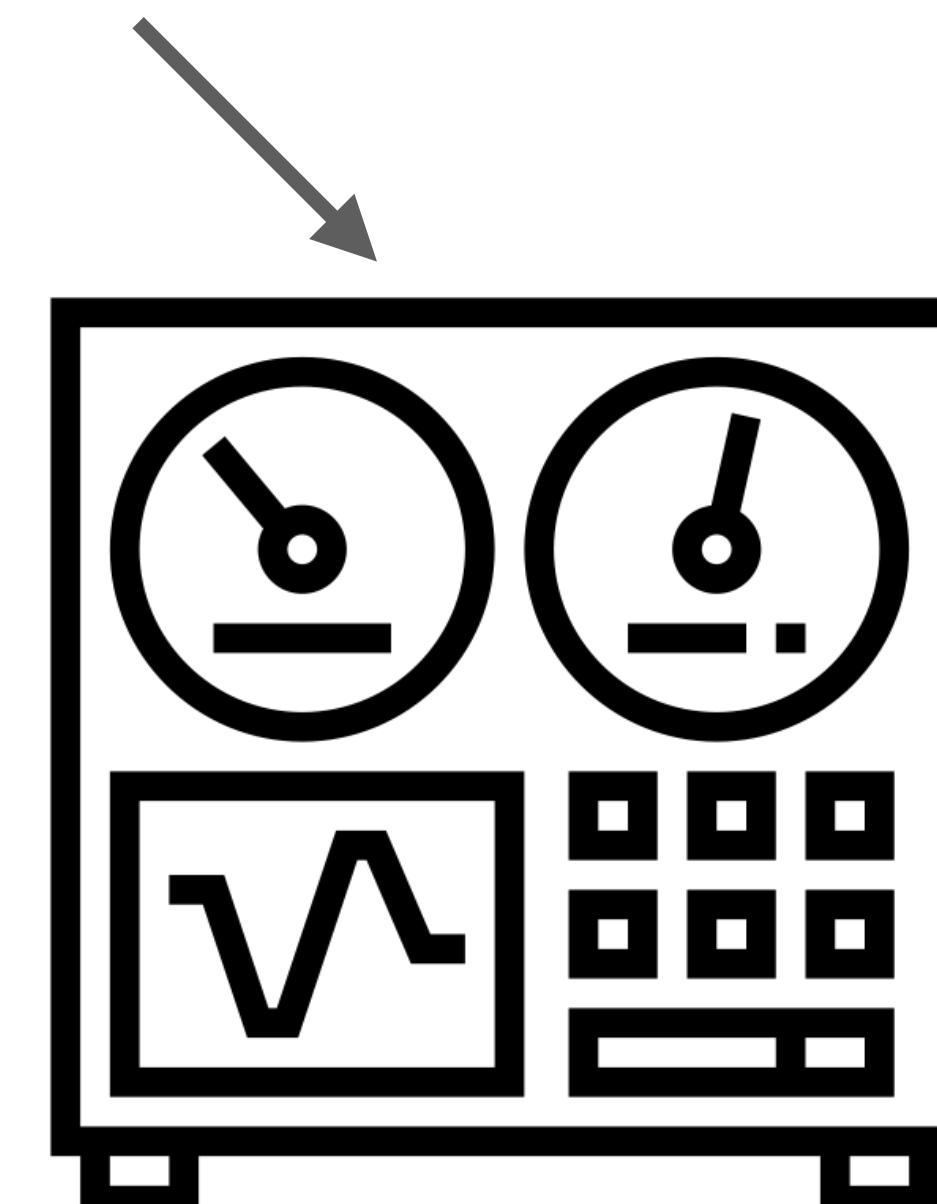
training

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testing

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training phase

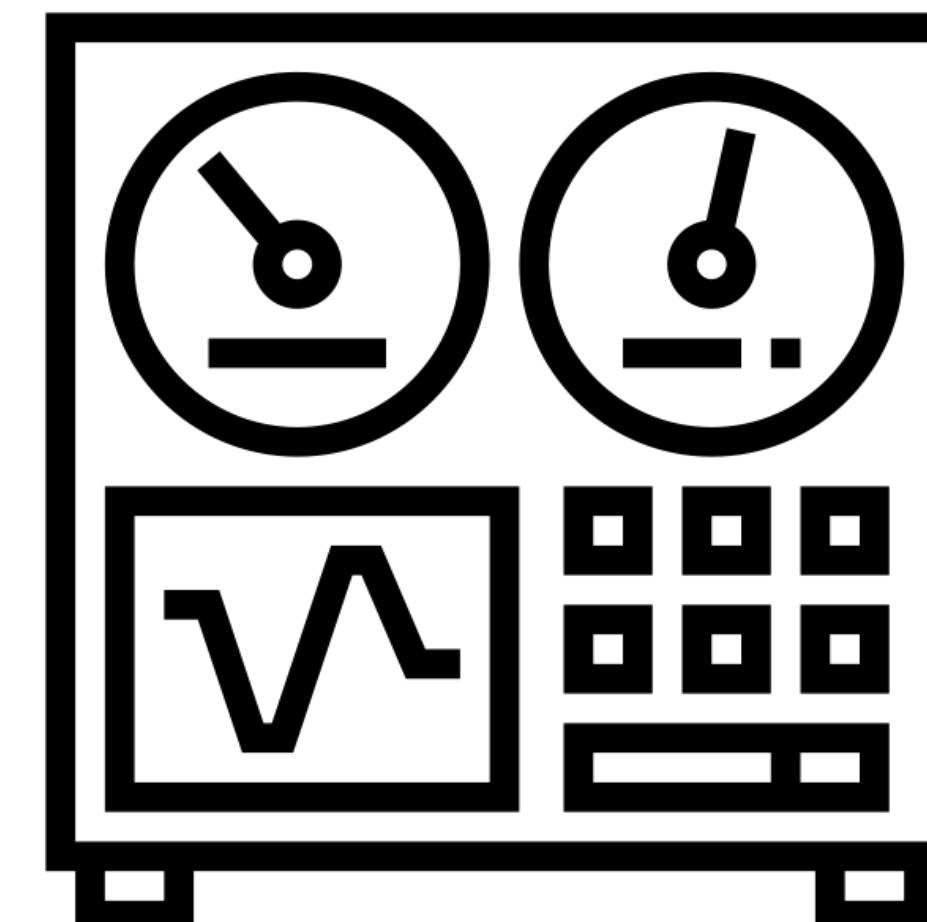


training

0	63	1	233	1
1	37	1	250	0
2	41	0	204	1
3	56	1	236	1
4	57	0	354	0
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testing

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training

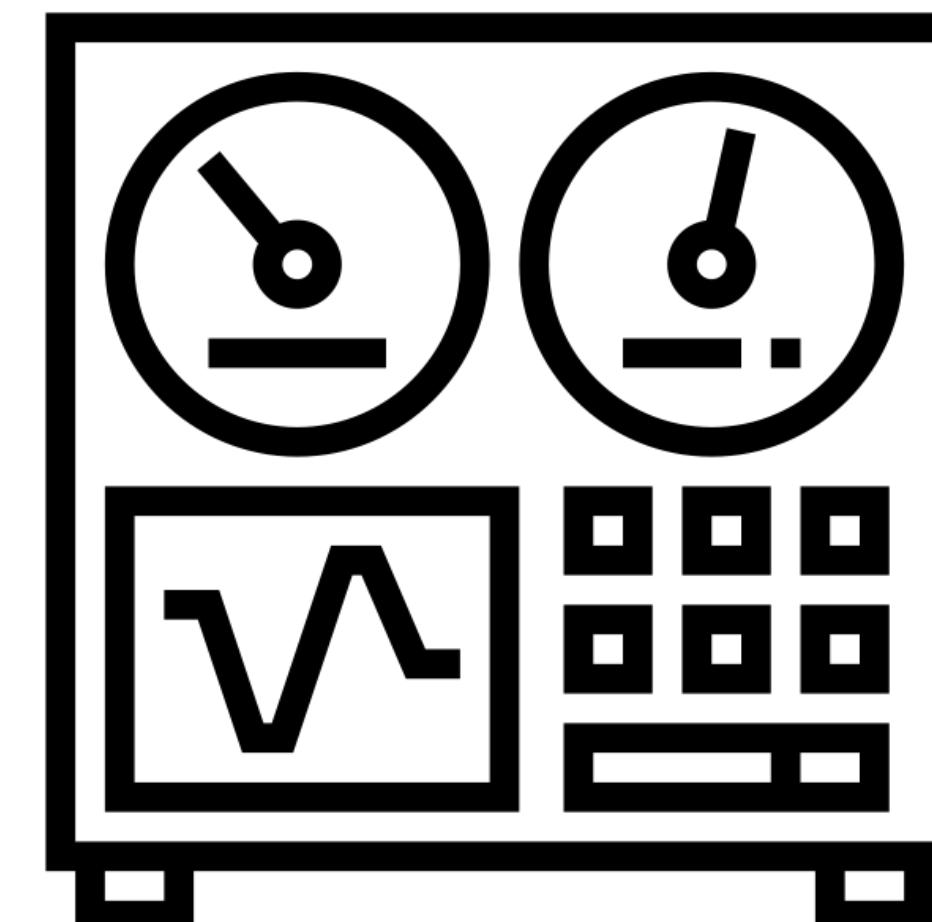
0	63	1	233	1
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9	57	1	168	1

testing

10	54	1	239
11	48	0	275
12	49	1	266
13	64	1	211
14	58	0	283

actual

1
0
1
0
1



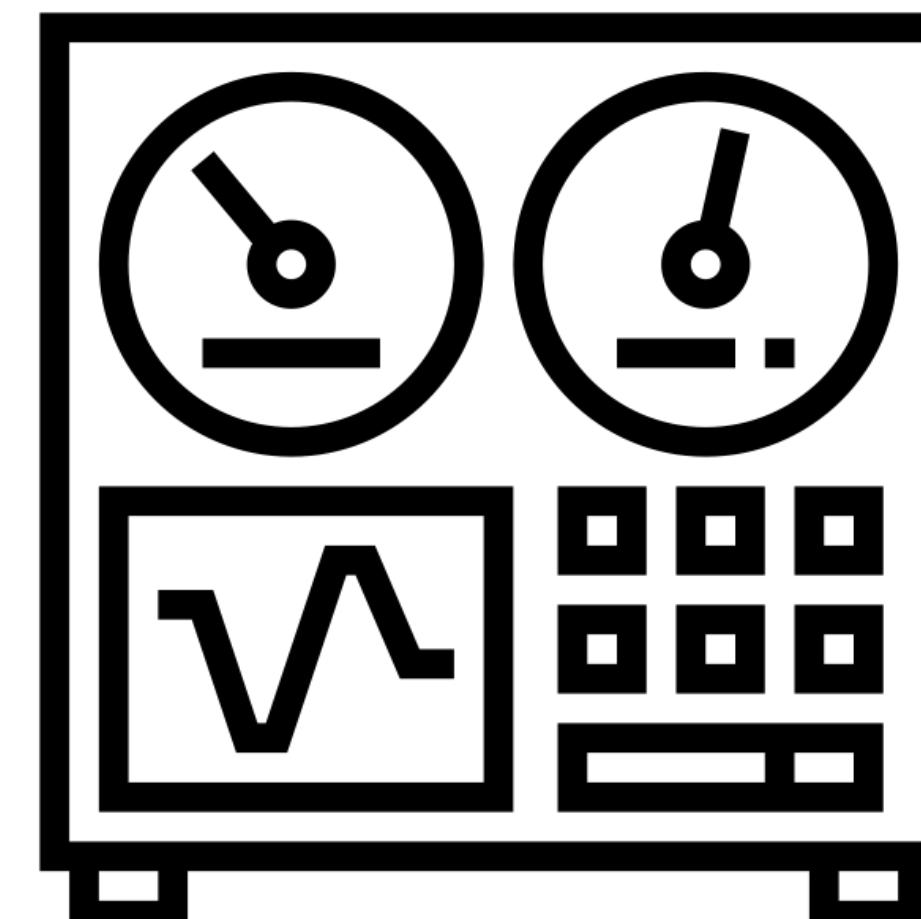
reserve the actual later for verification

training

0	63	1	233	1
1	37	1	250	0
2	41	0	204	1
3	56	1	236	1
4	57	0	354	0
5	57	1	192	0
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testing

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11	48	0	275
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13	64	1	211
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testing phase

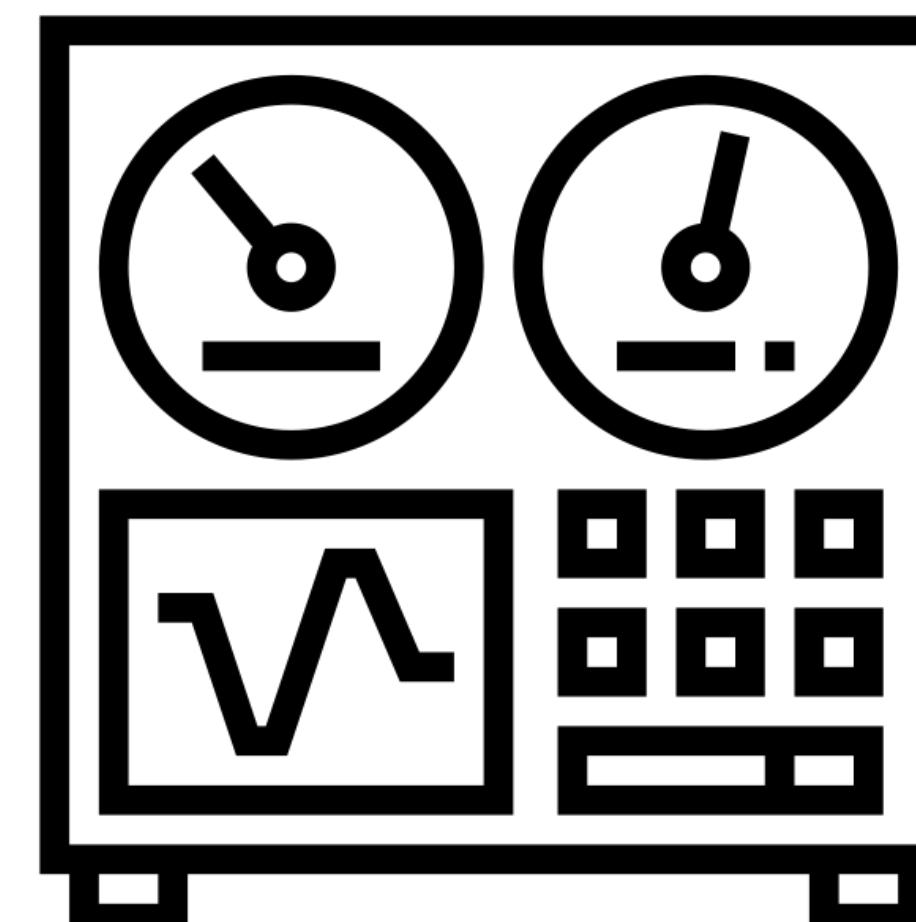
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testing

10	54	1	239
11	48	0	275
12	49	1	266
13	64	1	211
14	58	0	283

!!!!!!



generated
result

1
0
1
1
1

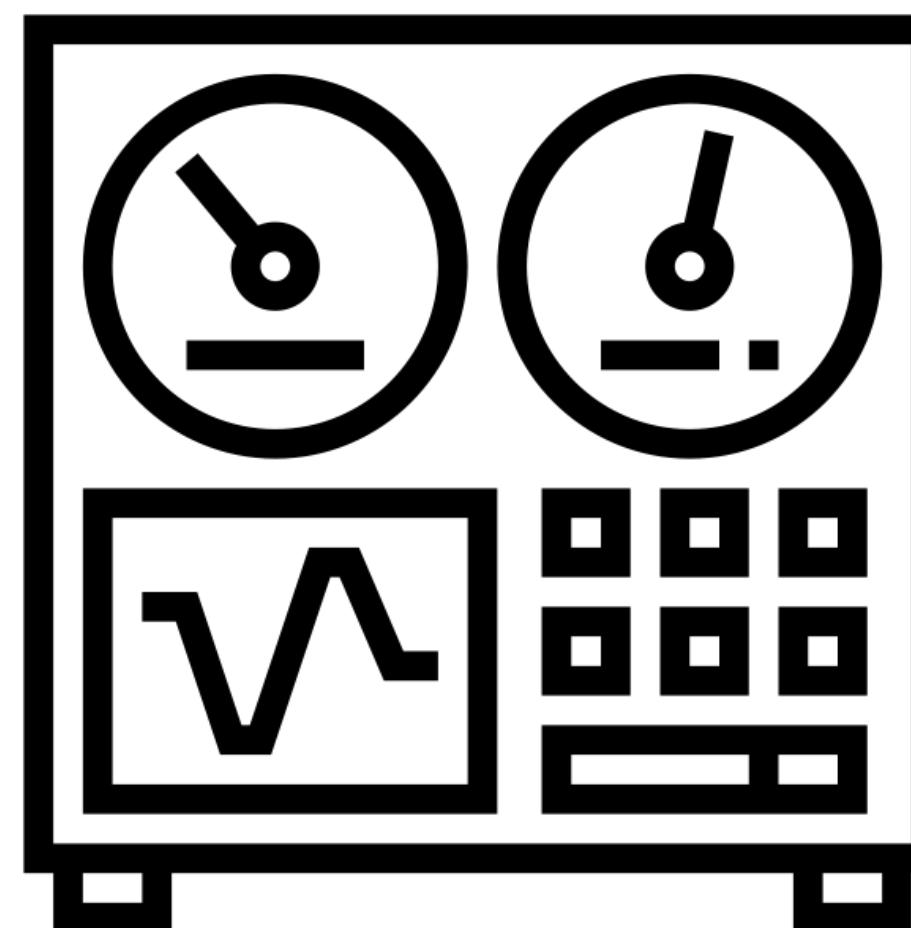
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testing

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11	48	0	275
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14	58	0	283

!!!!!!



generated

result

actual

1
0
1
1
1

1
0
1
0
1

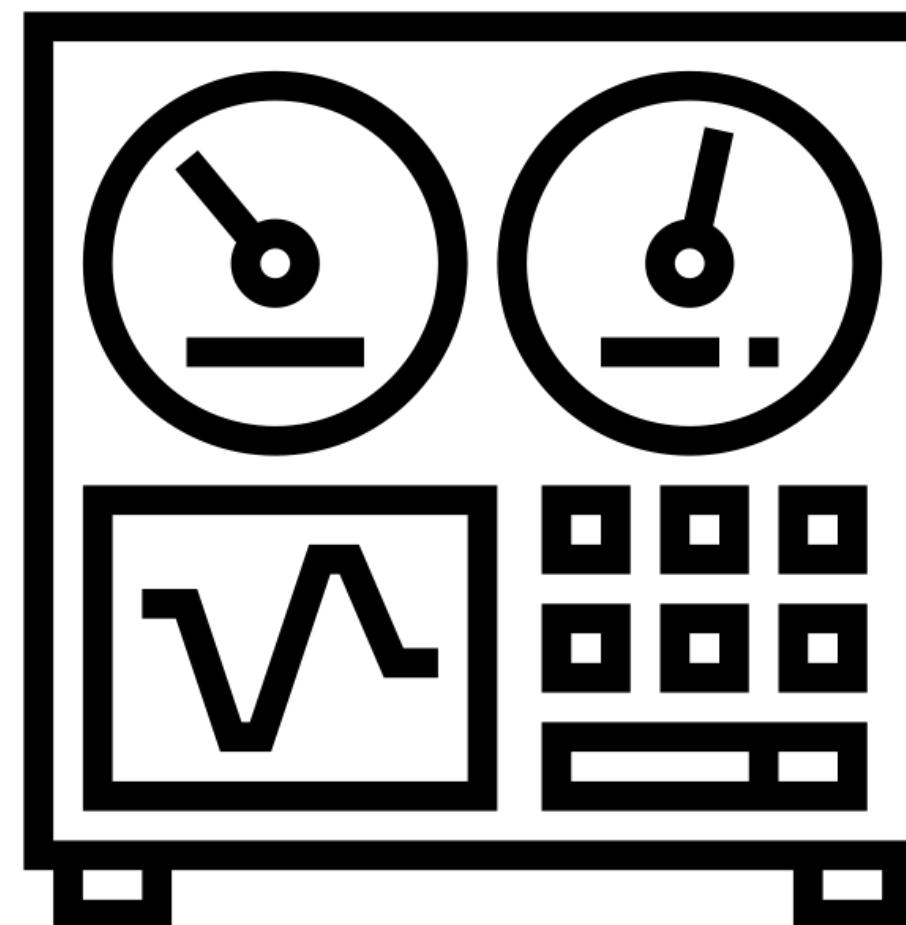
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testing

10	54	1	239
11	48	0	275
12	49	1	266
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14	58	0	283

!!!!!!



generated

result

actual

1
0
1
1
1

1
0
1
0
1

How did we do?

generated
result actual

1
0
1
1
1

1
0
1
0
1

How did we do?

Machine Learning Models

Machine Learning

KNN

Naive Bayes

Linear Regression

Deep Learning

Convolutional Neural Networks

Recurrent Neural Networks

Autoencoders

PROCESS OF FACIAL RECOGNITION

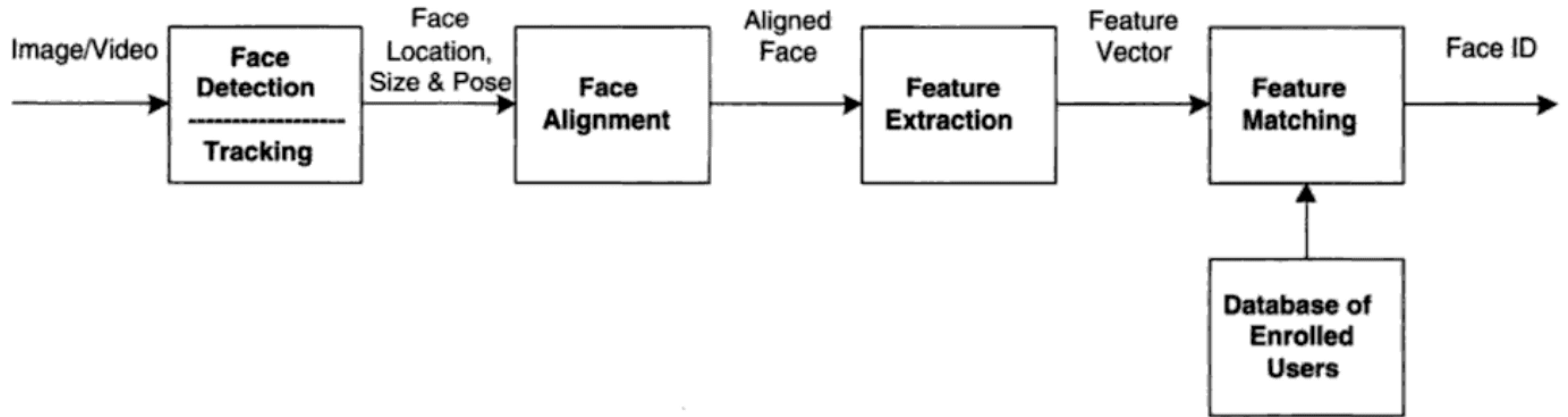


Fig. 1.2. Face recognition processing flow.

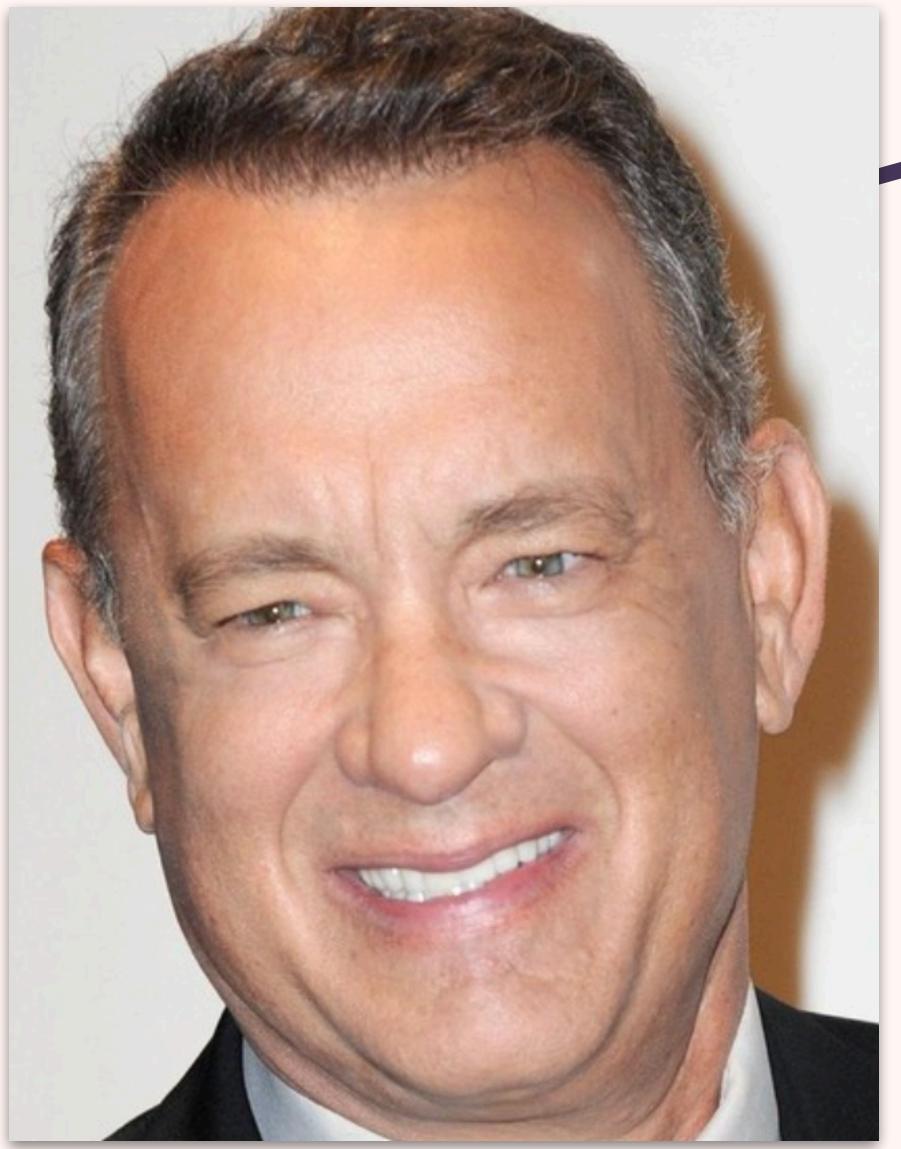
PROCESS OF FACIAL RECOGNITION

- **Extract the features from the image**
 - **Train the Machine Learning Model to identify whatever face there is in the image**
 - **Once it captures to important features of your face, then it usually is stored in a coordinate area or address**
 - **The coordinate area is multidimensional**
 - **Your face; Separate from the everyone else has a specialized address where your face is located.**
-

z

y

x



z

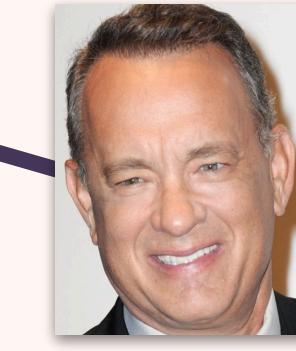
y

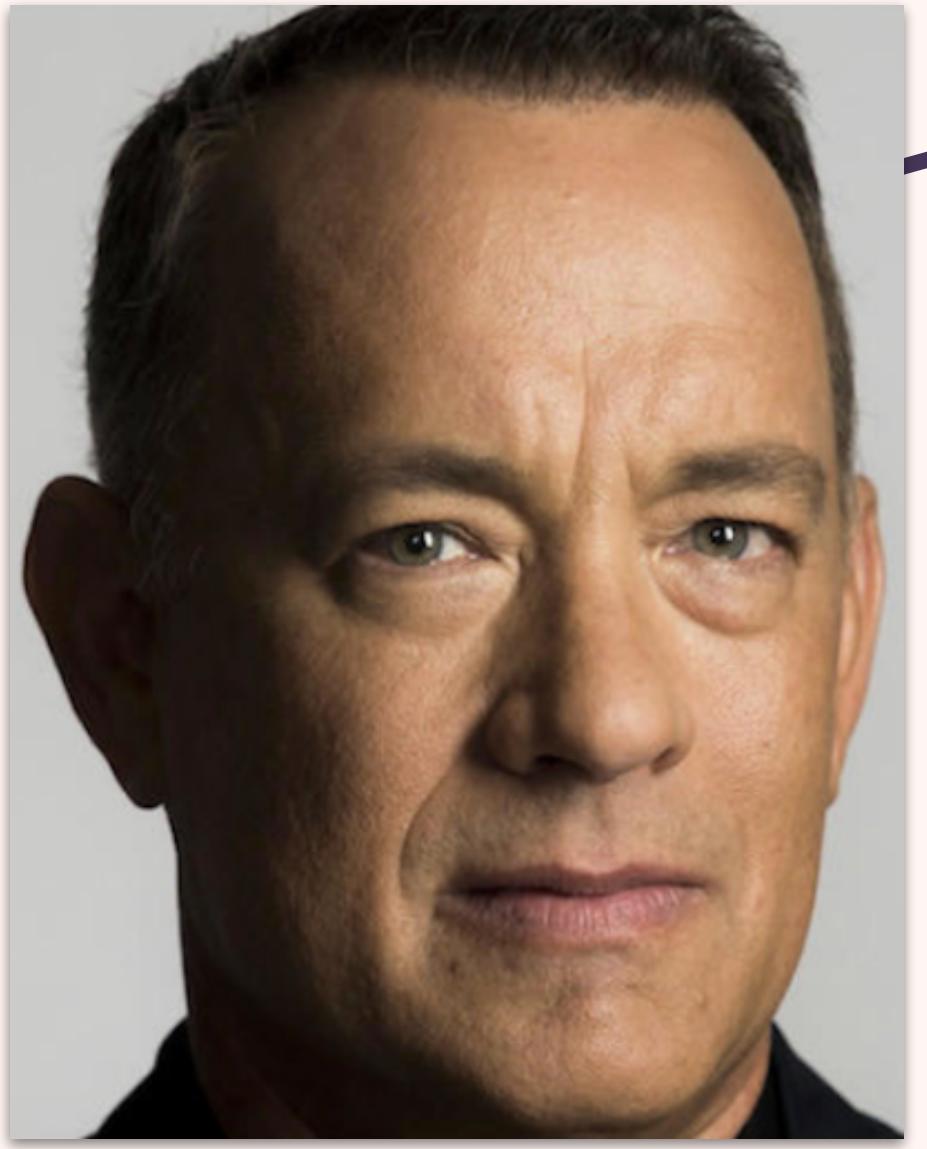
x

z

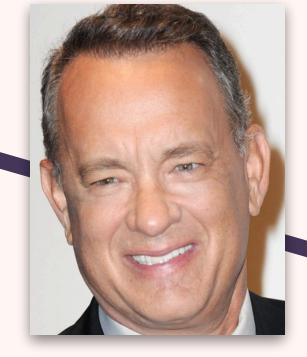
y

x





z



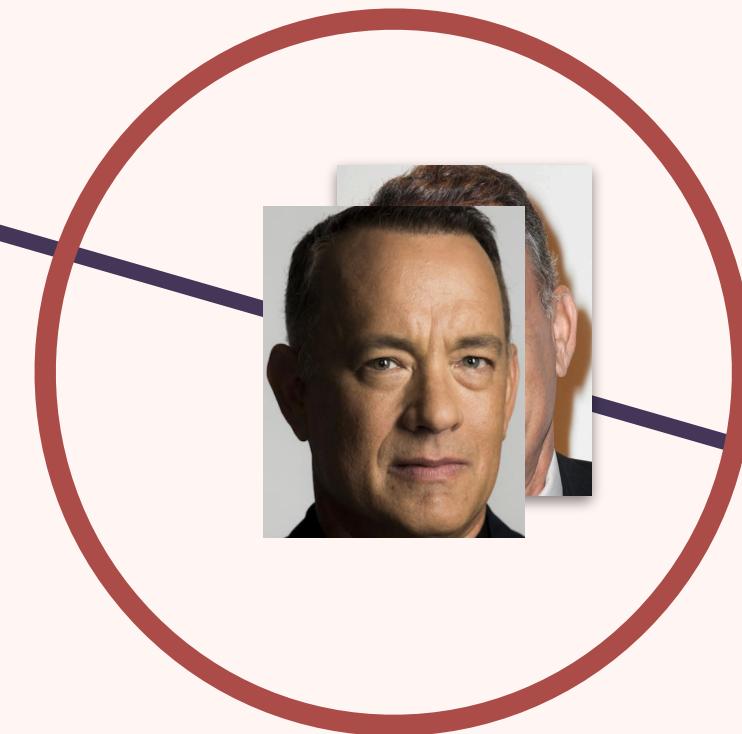
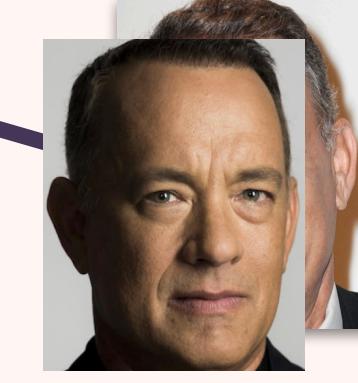
y

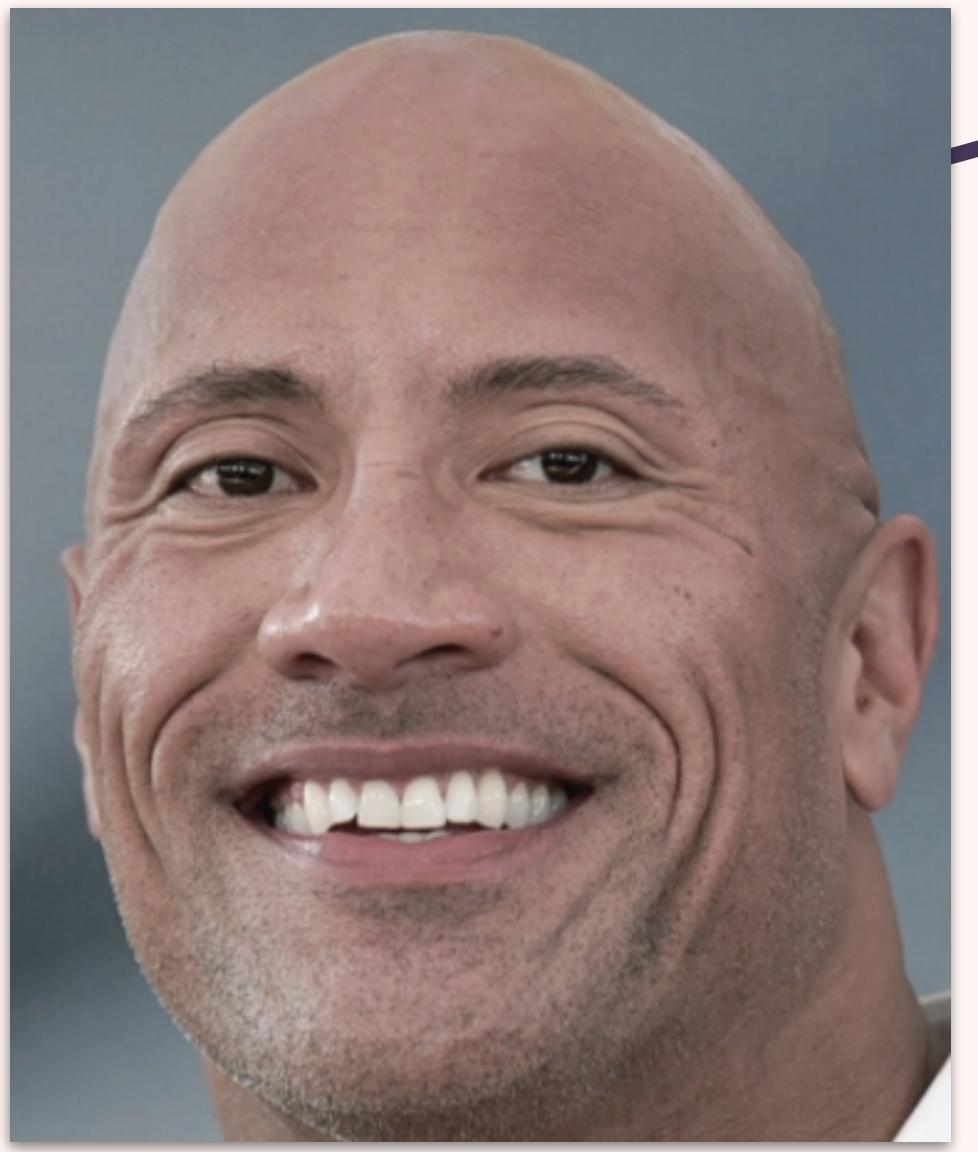
x

z

y

x

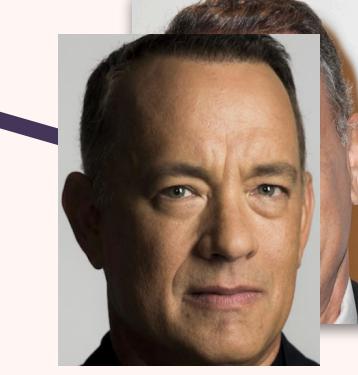


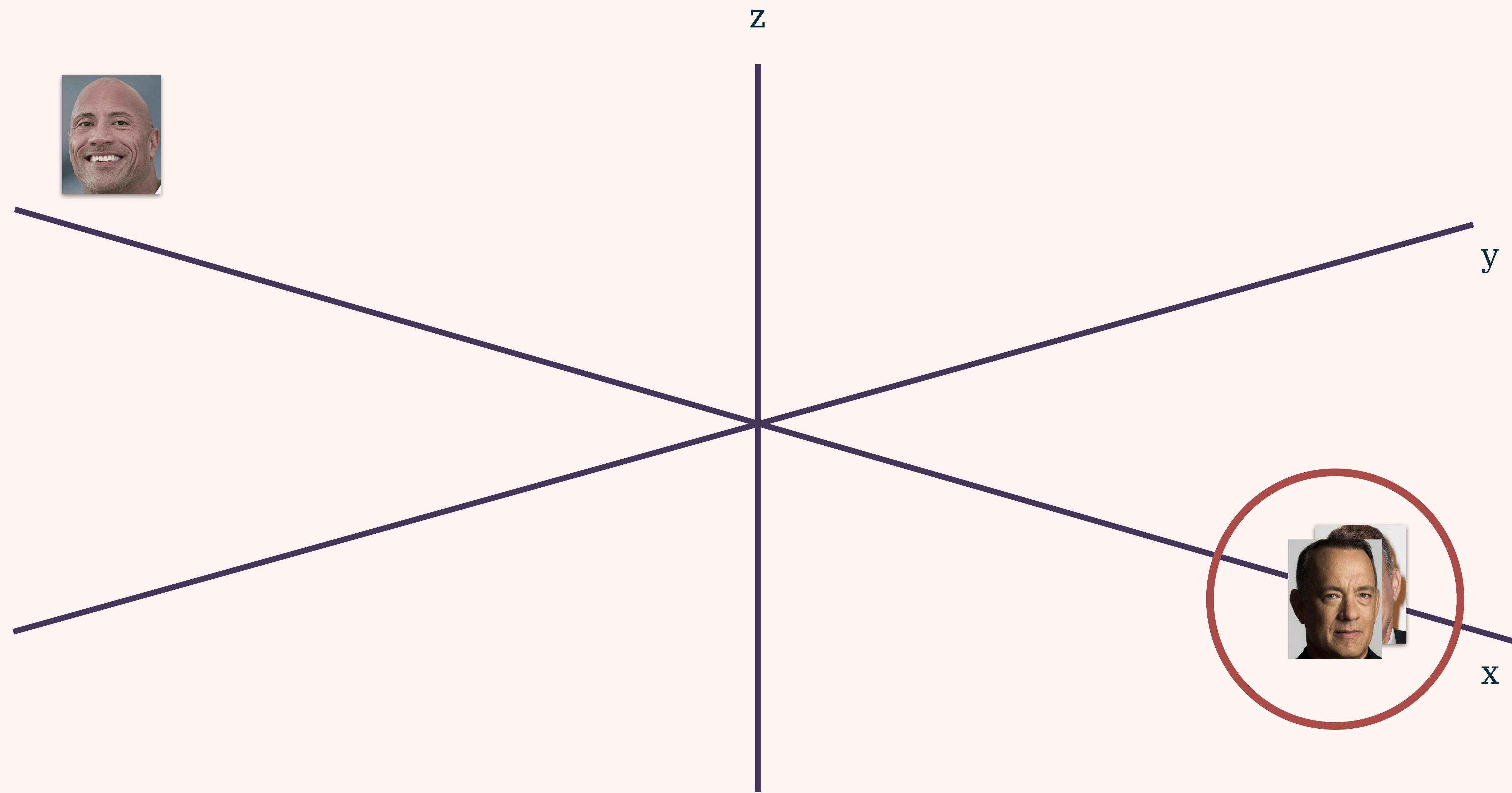


z

y

x





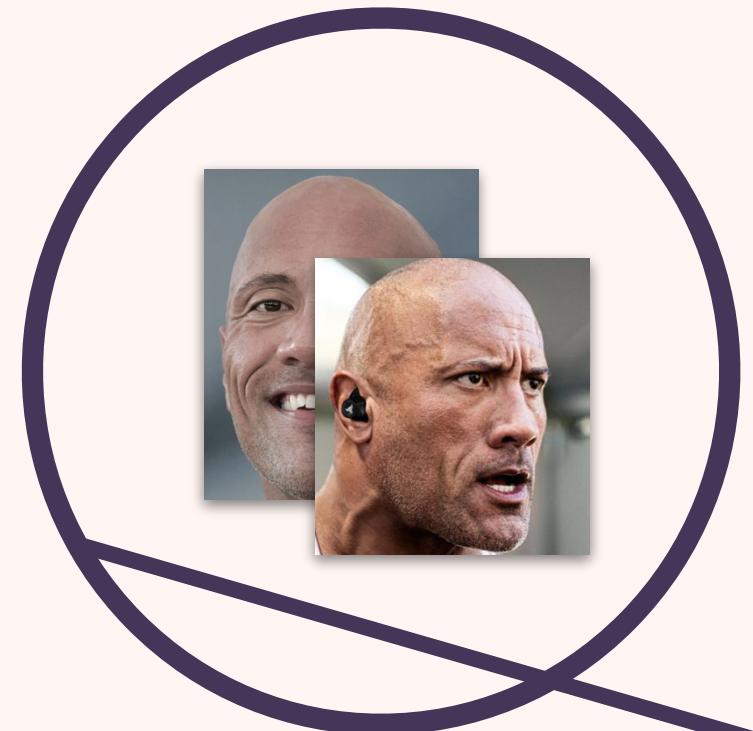


z

y

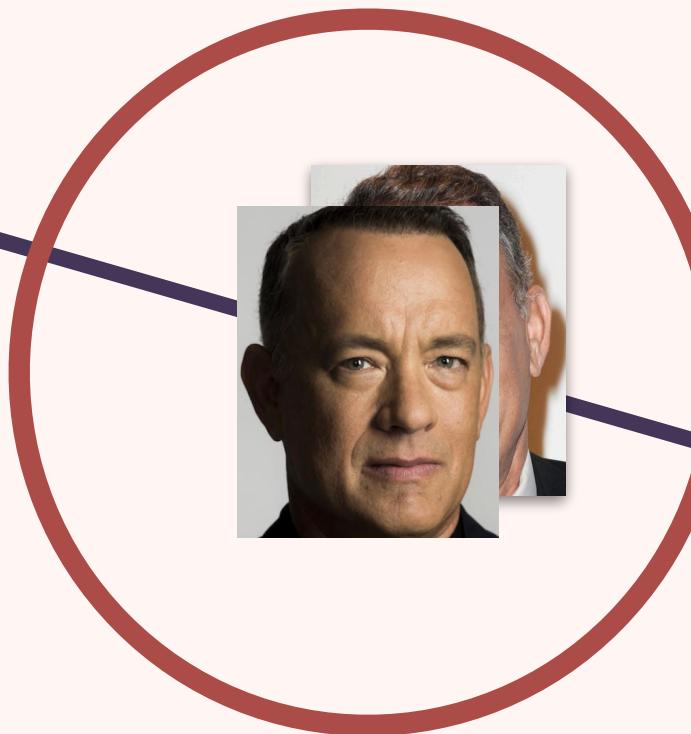
x



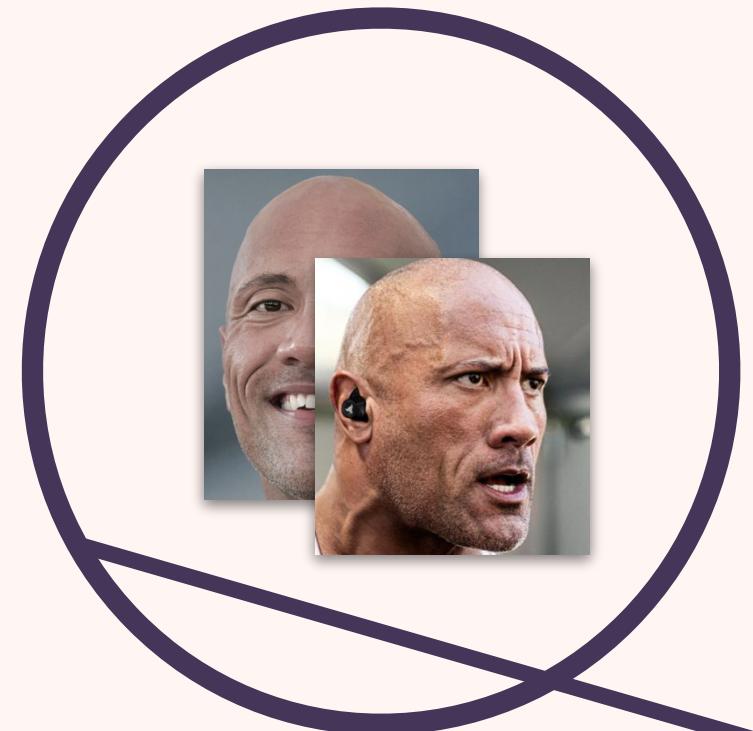


z

y

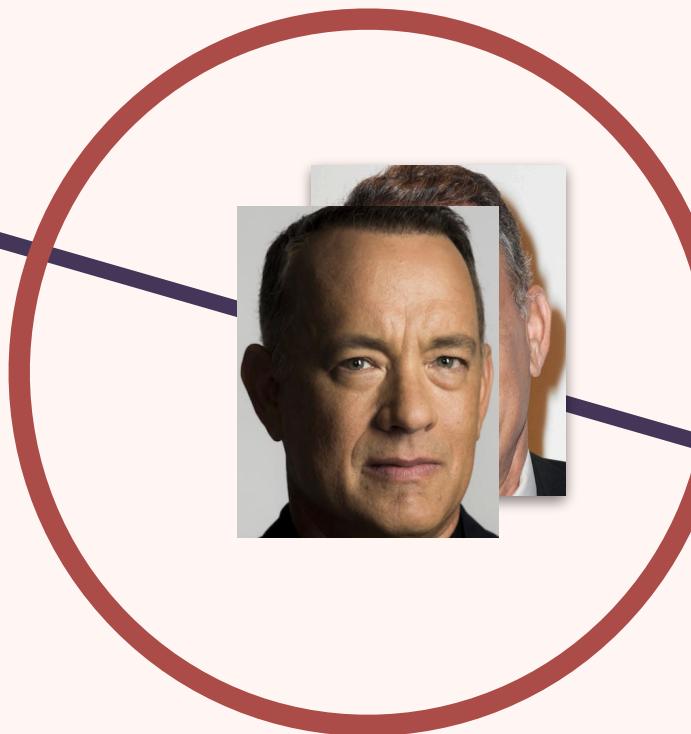


x

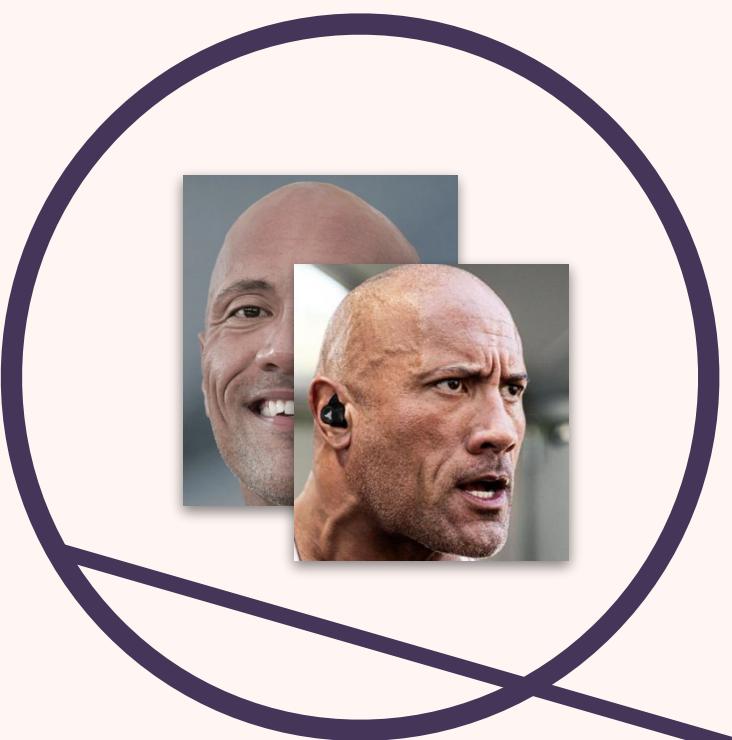


z

y



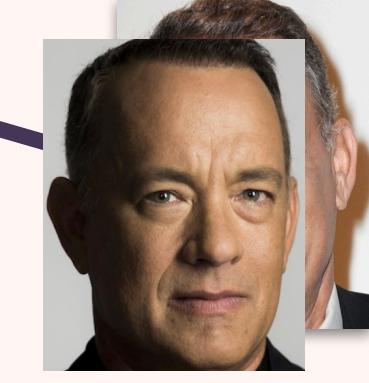
x



z

y

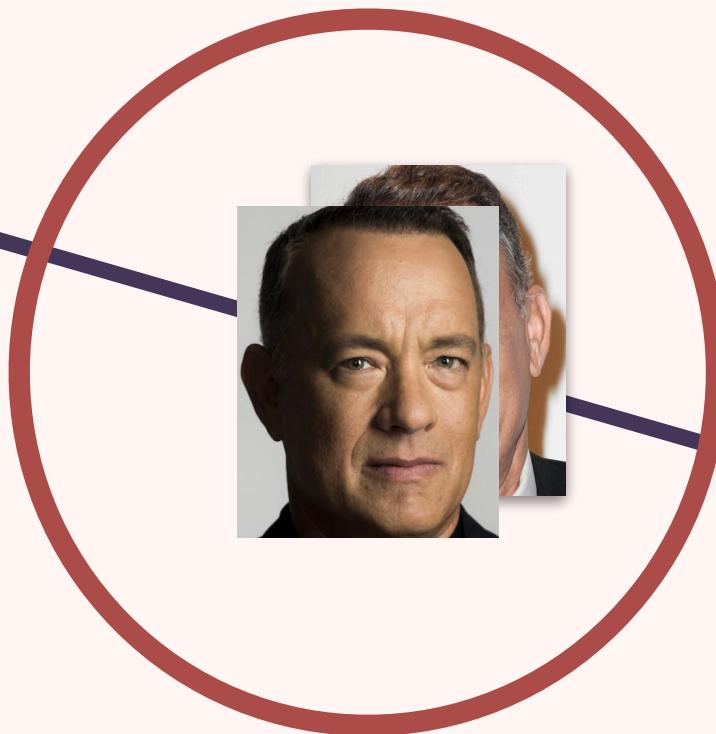
x





z

y



x

**THIS IS ACTUALLY
MULTIDIMENSIONAL (>3)**

**ROTATION, OBSCURING
FACES**

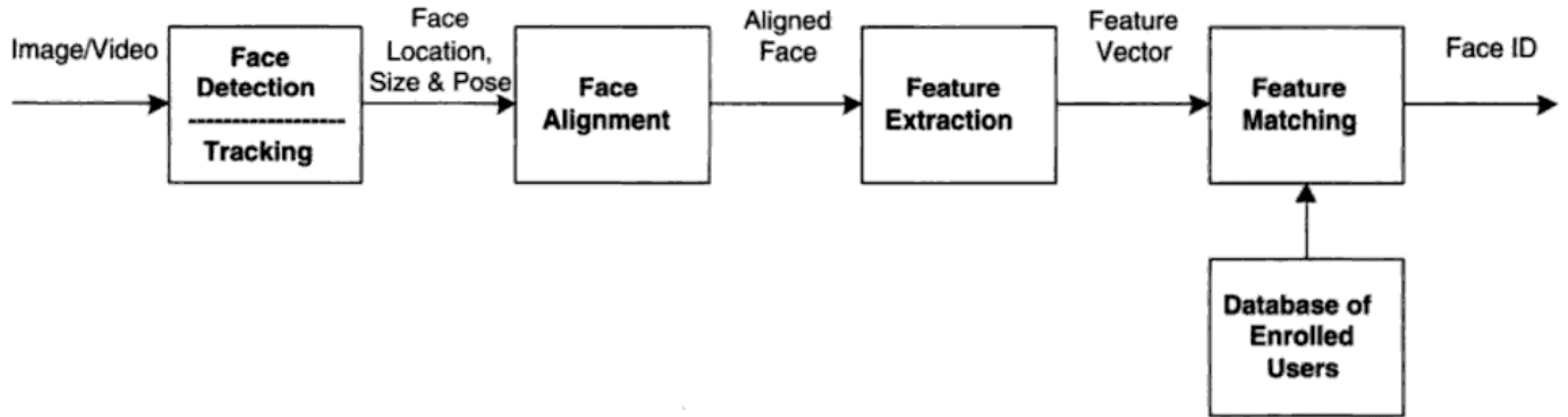


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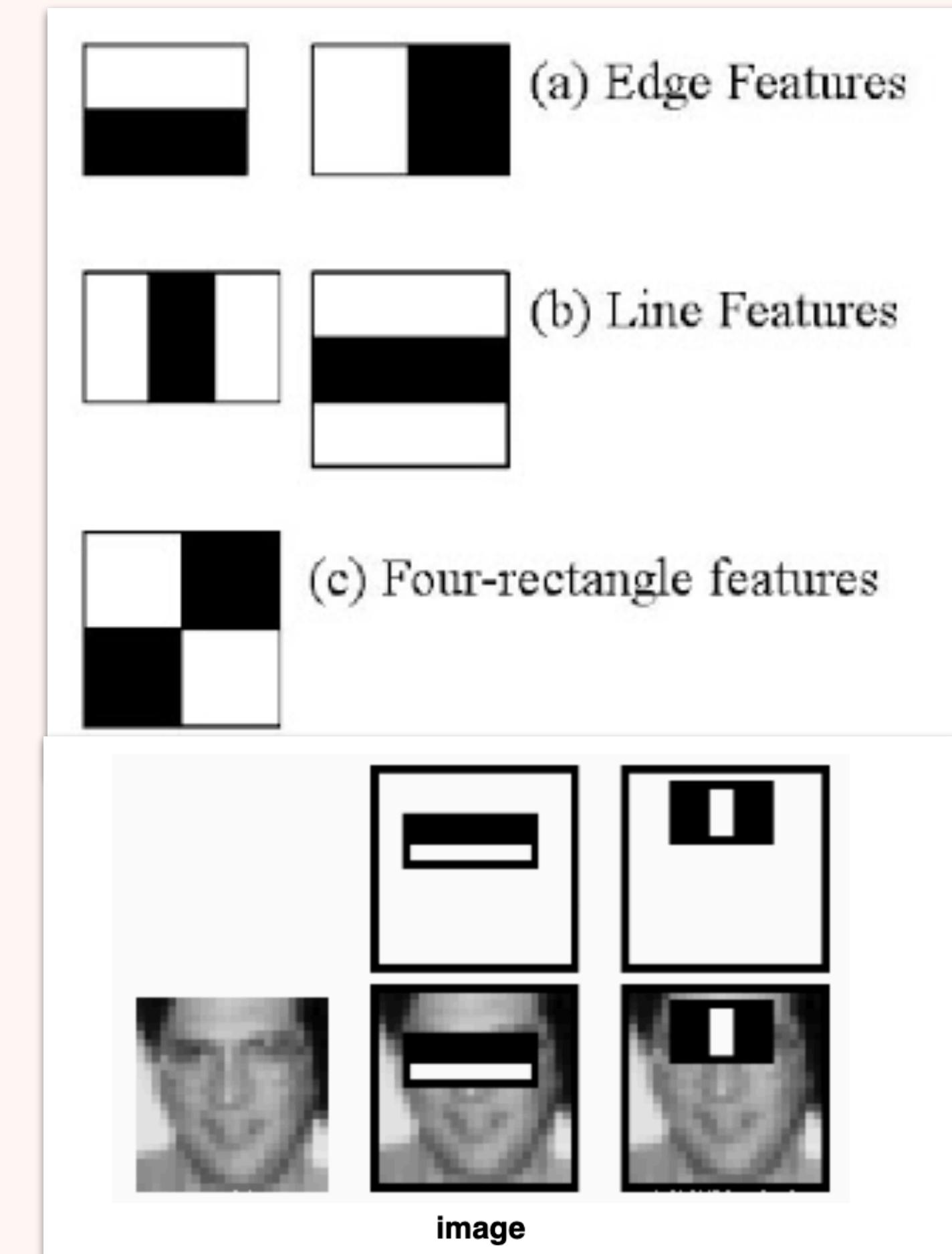


FACIAL DETECTION CLASSIFIERS

HAAR CASCADE

HAAR CLASSIFIER

- Machine learning object detection program that identifies objects in an image and video
- Initially, the algorithm needs a lot of positive images (images of faces) and negative images (images without faces) to train the classifier
- Each feature is a single value obtained by subtracting sum of pixels under the white rectangle from sum of pixels under the black rectangle
- Features chosen are done Adaboost to improve on performance



MTCNN

MTCNN

- **Facial Detection in Python**
- **OpenCV>=4.1 and Keras>=2.0.0**
- **Returns JSON Representation where the face is located and where important features are located**
- **Eyes, Mouth, Nose**



FACIAL FEATURE EXTRACTION

DIMENSIONALITY REDUCTION

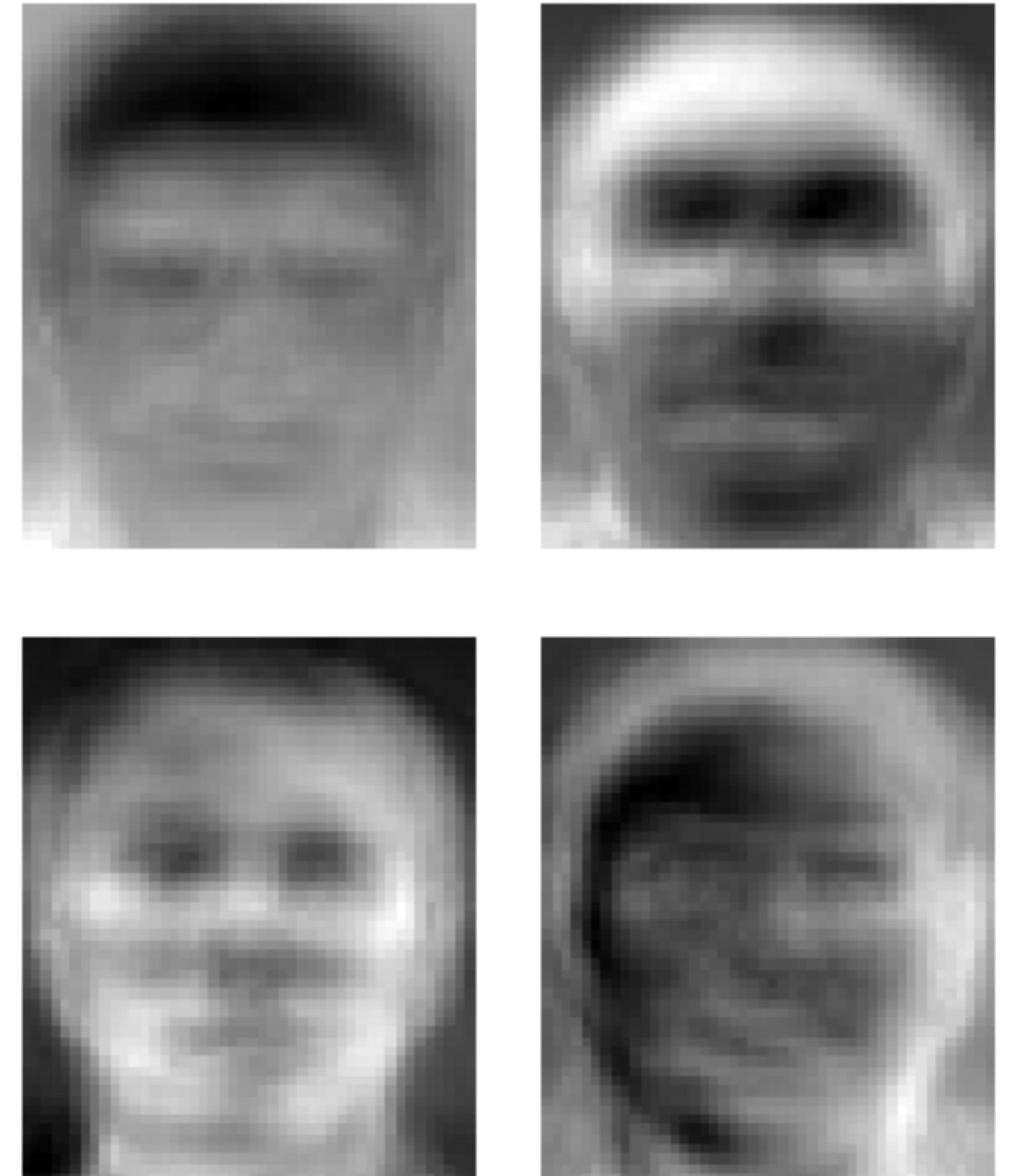
DIMENSIONALITY REDUCTION

- Take an image (or any data) in high dimensions and reduce it to lower dimensions
 - For example, a 28 x 28 image plotted shows a picture but creating a row of data of every pixel of a single image will create a 784 columns.
 - 784 columns = 784 features = 784 dimensions (That's a lot of inputs)
 - Handling that much data might be inefficient, so can we just keep *the good stuff*?
 - Feature projection (also called Feature extraction) transforms the data from the high-dimensional space to a space of fewer dimensions
-

EIGENFACES

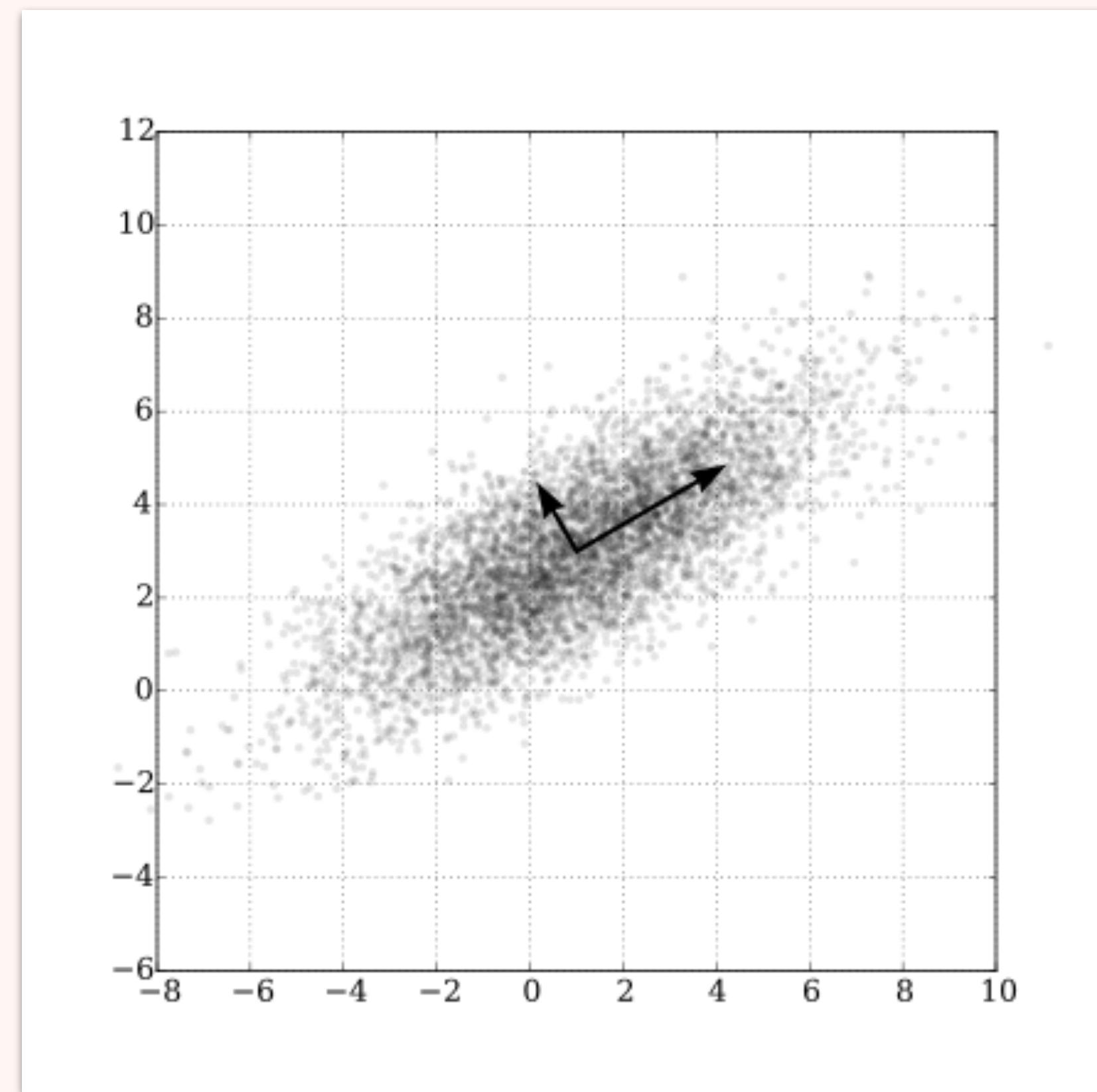
EIGENFACES

- Set of eigenvectors
- The eigenvectors are derived from the covariance matrix of the **probability distribution** over the **high-dimensional vector space** of face images
- Right Displays the EigenFaces from the mean face
- Do not recommend posting these pictures in a child's nursery



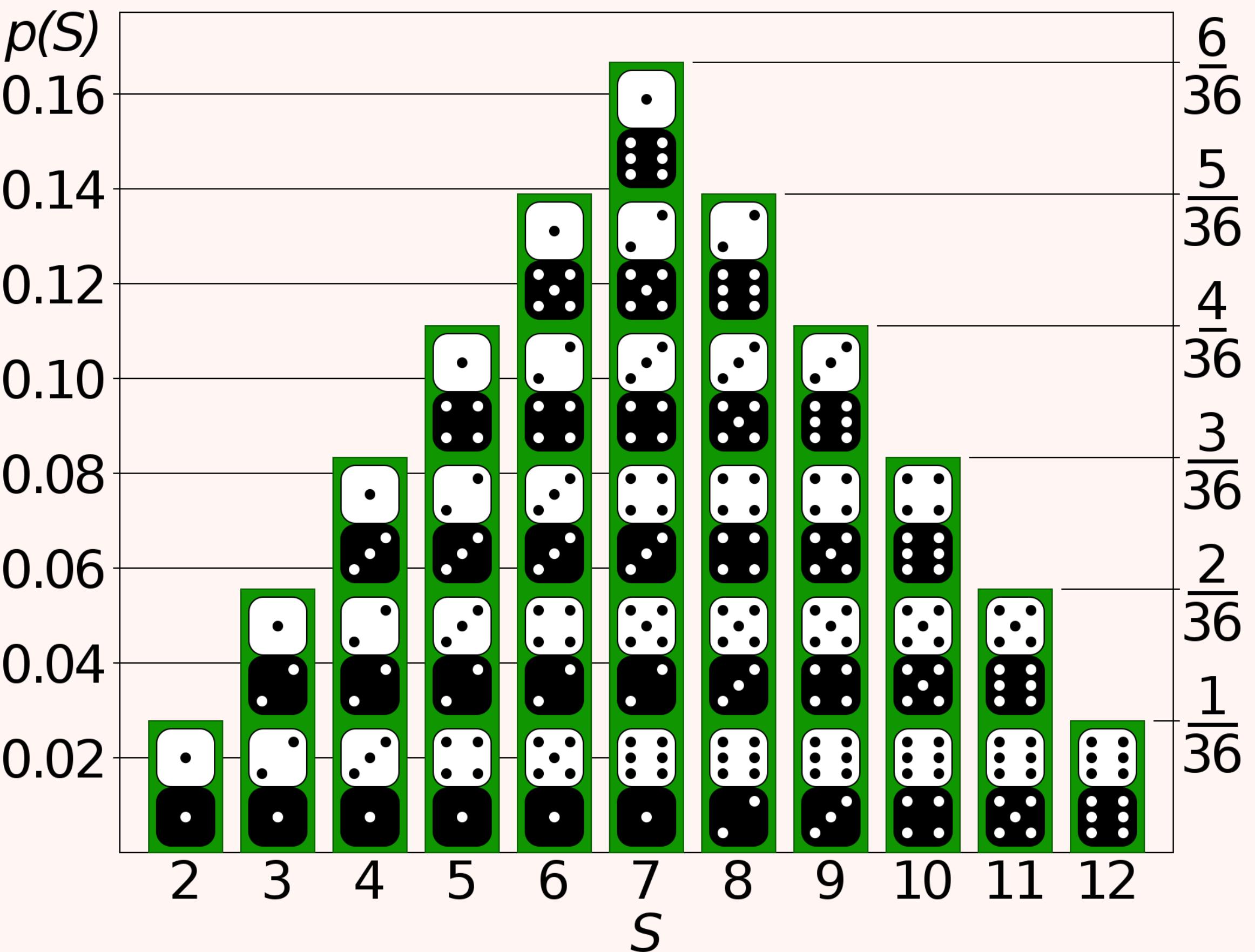
COVARIANCE MATRIX?

- **Square matrix giving the covariance between each pair of elements of a given random vector**
- **Covariance: The speed of the windmill is covariant with the speed of the wind**



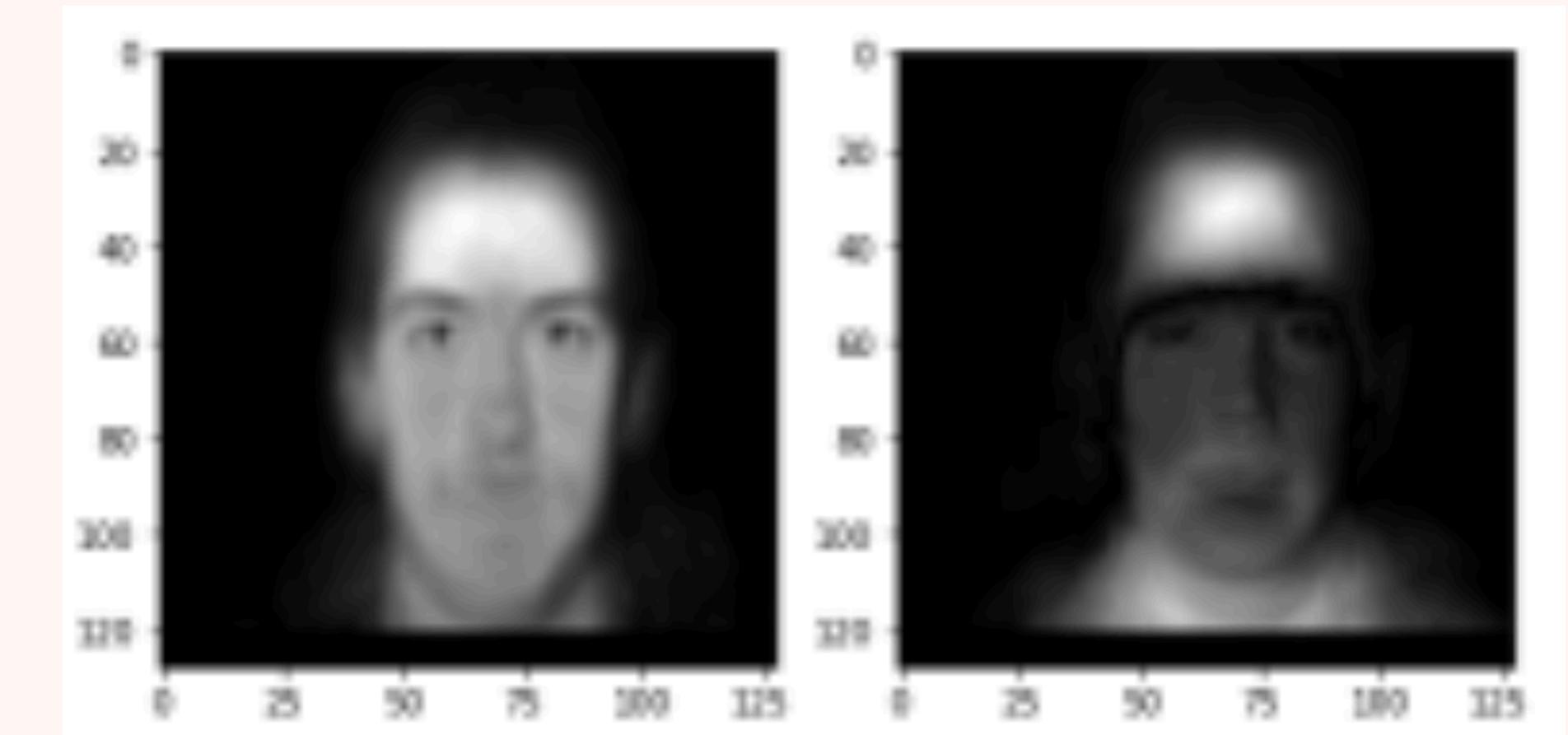
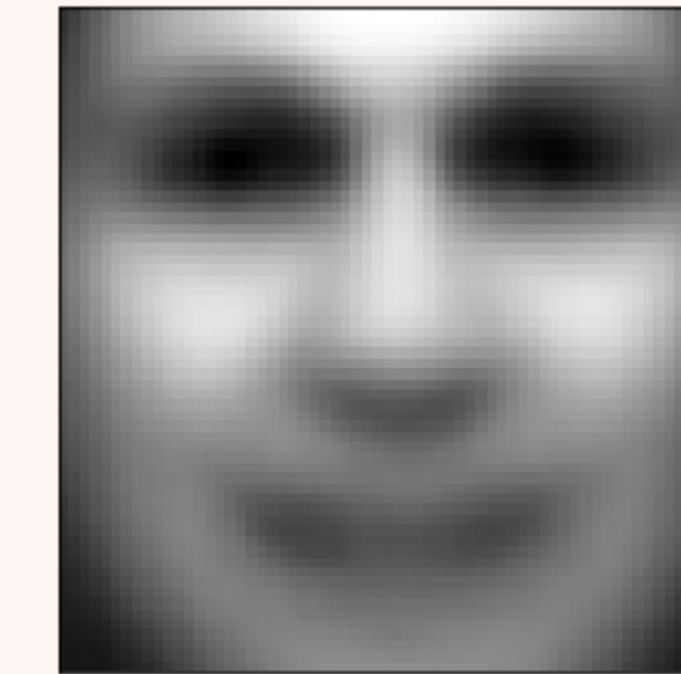
PROBABILITY DISTRIBUTION

- A probability distribution is the mathematical function that gives the probabilities of occurrence of different possible outcomes for an experiment
- Pictured Right: Distribution of rolling two dice. There is a probability that you would get a seven more than other combinations



BACK TO EIGENFACES

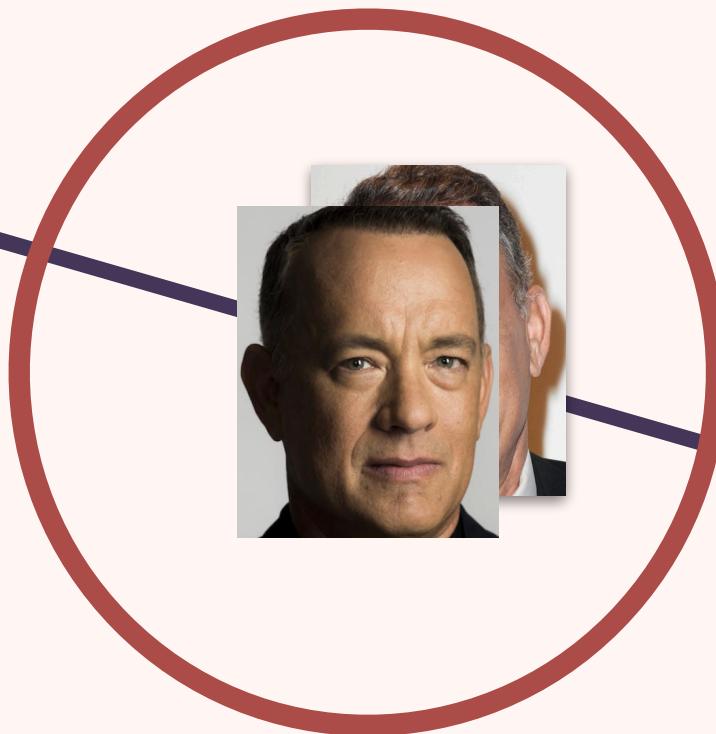
- **Using Principle Component Analysis, PCA, we can extract the main components of a face or many faces**
- **First we have to establish a *mean face*, displayed on right**
- **We have a group of other faces called *eigenfaces*.**
- **Our face would have a percentage signature, I may have 30% match of values from one eigenface, 10% from another, and even negative values.**





z

y



x

DEMO: EIGENFACE, NUMBERS

FACIAL LANDMARKS

FACIAL LANDMARKS

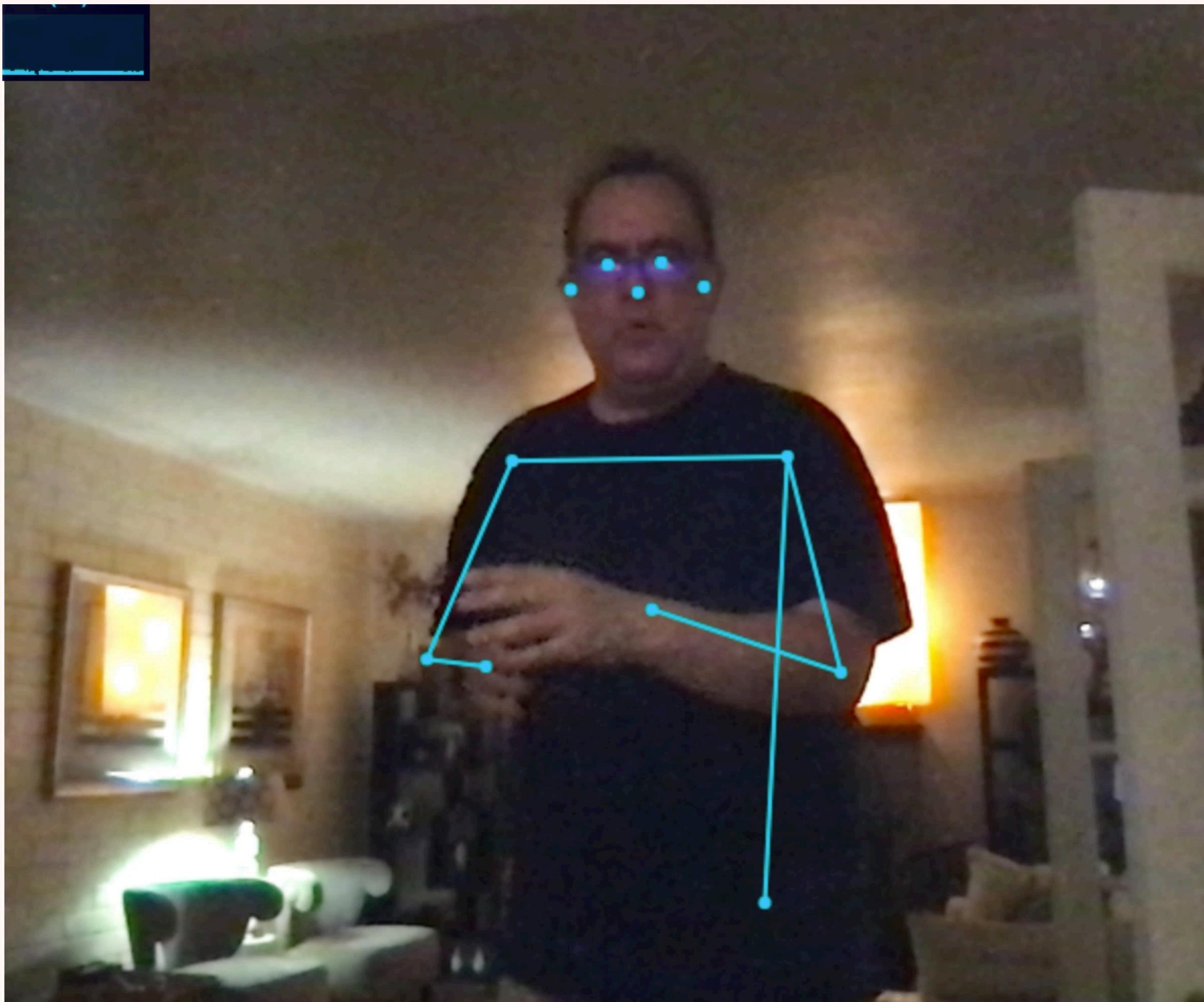
- **Used to extract the important positions of a face**
 - **Eyes, Eyebrows, Nose, Mouth, Jawline**
 - **Done after Facial Recognition, e.g. Haar Cascades, getting the bounded box**
 - **Use Facial Landmarks to find the important points**
 - **Part of the DLib Package**
-

DEMO: FACIAL DETECTION AND RECOGNITION

NODAL POINTS

NODAL POINTS

- **Used to extract the important positions of a face**
 - **Eyes, Eyebrows, Nose, Mouth, Jawline**
 - **Done after Facial Recognition, e.g. Haar Cascades, getting the bounded box**
 - **Use Facial Landmarks to find the important points**
 - **Part of the DLib Package**
-



<https://storage.googleapis.com/tfjs-models/demos/posenet/camera.html>

TECHNOLOGIES IN LANGUAGES

DLIB

DLIB

- <http://dlib.net/>
 - **Dlib is a modern C++ toolkit containing machine learning algorithms and tools for creating complex software in C++ to solve real world problems**
 - **Machine Learning Algorithms**
 - **Deep Learning**
 - **Multiclass SVM**
 - **High Quality Facial Recognition**
-

OPENCV

OPENCV

- <https://opencv.org/>
- **(Open Source Computer Vision Library) is an open source computer vision and machine learning software library.**
- **2500 optimized algorithms**
- **C++, Python, Java and MATLAB interfaces and supports Windows, Linux, Android and Mac OS**
- **Full-featured CUDA and OpenCL**
- **OpenCV is written natively in C++ and has a templated interface that works seamlessly with STL containers.**



OpenCV

LANGUAGE SUPPORT

PYTHON

 **ANACONDA.NAVIGATOR**

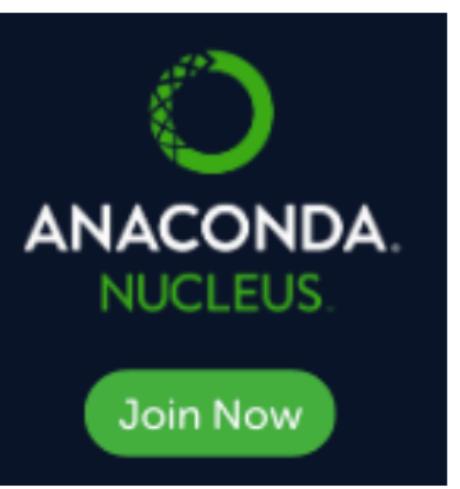
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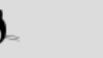
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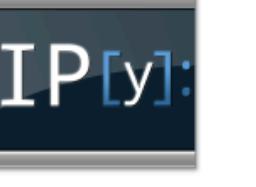
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Anaconda Navigator

Applications on Refresh

 Datalore Online Data Analysis Tool with smart coding assistance by JetBrains. Edit and run your Python notebooks in the cloud and share them with your team. Launch	 IBM Watson Studio Cloud IBM Watson Studio Cloud provides you the tools to analyze and visualize data, to cleanse and shape data, to create and train machine learning models. Prepare data and build models, using open source data science tools or visual modeling. Launch	 JupyterLab 2.2.6 An extensible environment for interactive and reproducible computing, based on the Jupyter Notebook and Architecture. Launch	 Notebook 6.1.4 Web-based, interactive computing notebook environment. Edit and run human-readable docs while describing the data analysis. Launch
 Qt Console 4.7.7 PyQt GUI that supports inline figures, proper multiline editing with syntax highlighting, graphical calltips, and more. Launch	 Spyder 4.1.5 Scientific PYthon Development EnviRonment. Powerful Python IDE with advanced editing, interactive testing, debugging and introspection features Launch	 VS Code 1.55.0 Streamlined code editor with support for development operations like debugging, task running and version control. Launch	 dioptas 0.4.1

JAVA

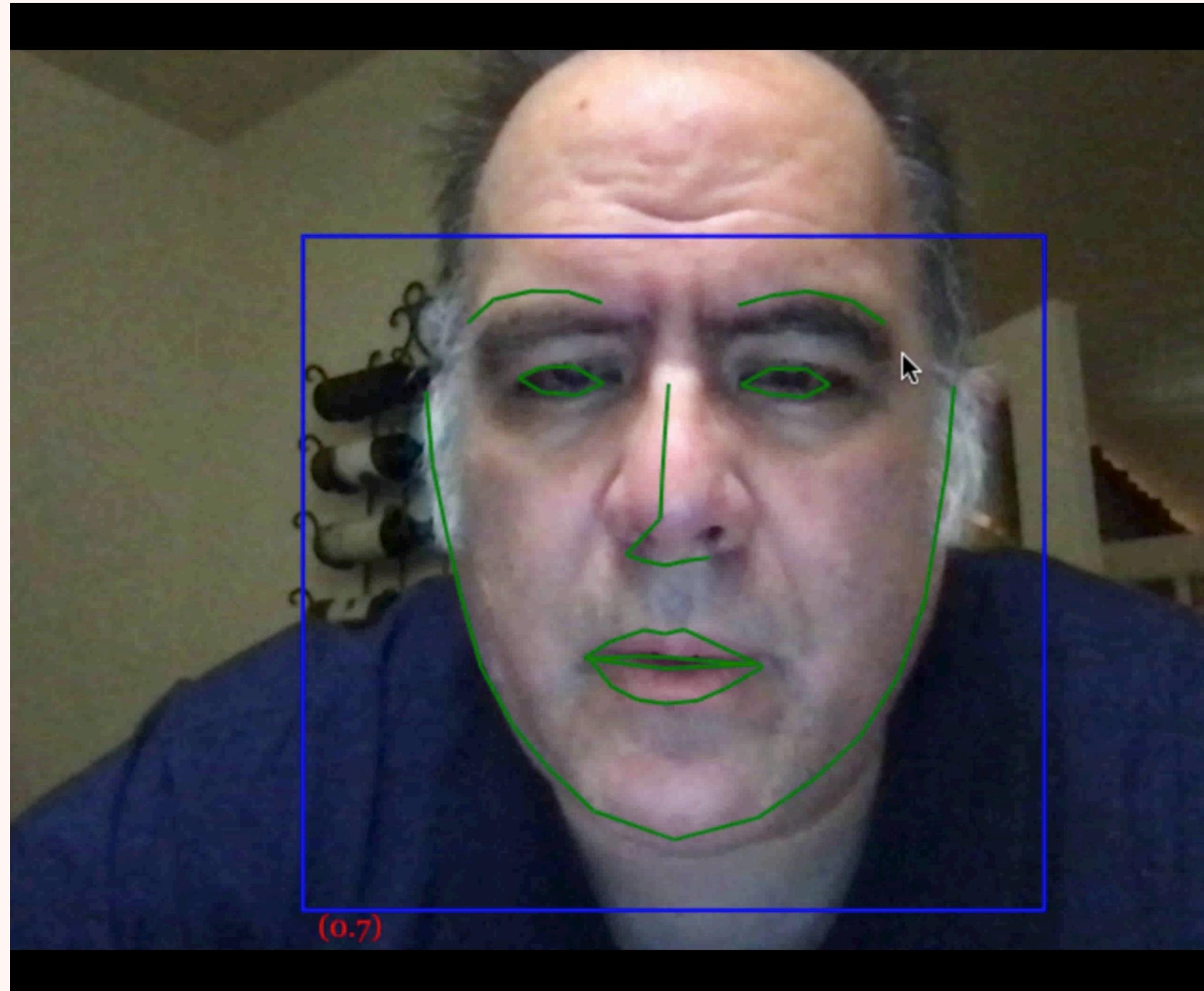


OpenCV



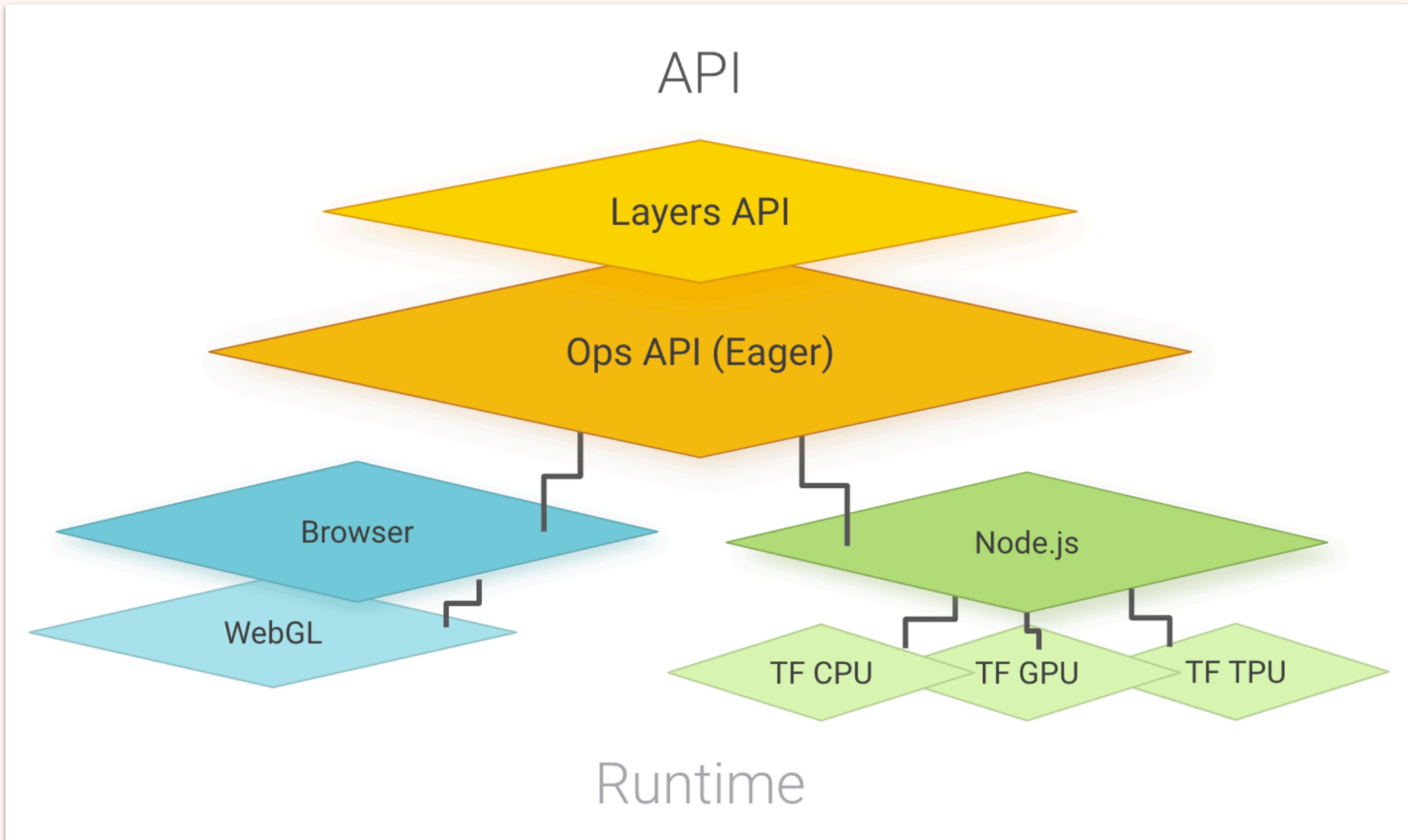
- **OpenCV is available by Maven Repository**
- **Bridge Between Language not that mature**
- **Extensive communication with JNI**

JAVASCRIPT

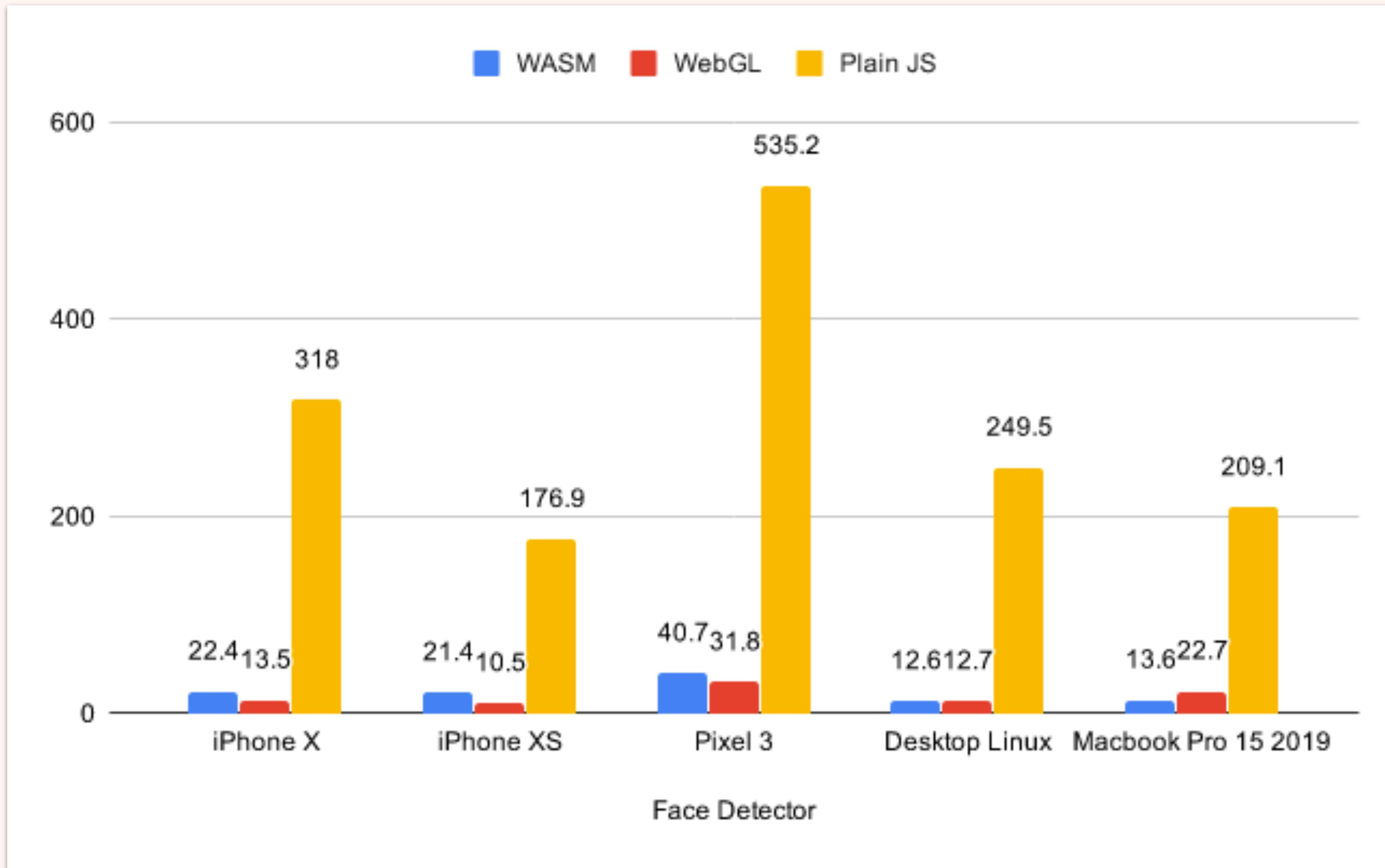


https://justadudewhohacks.github.io/face-api.js/webcam_face_tracking

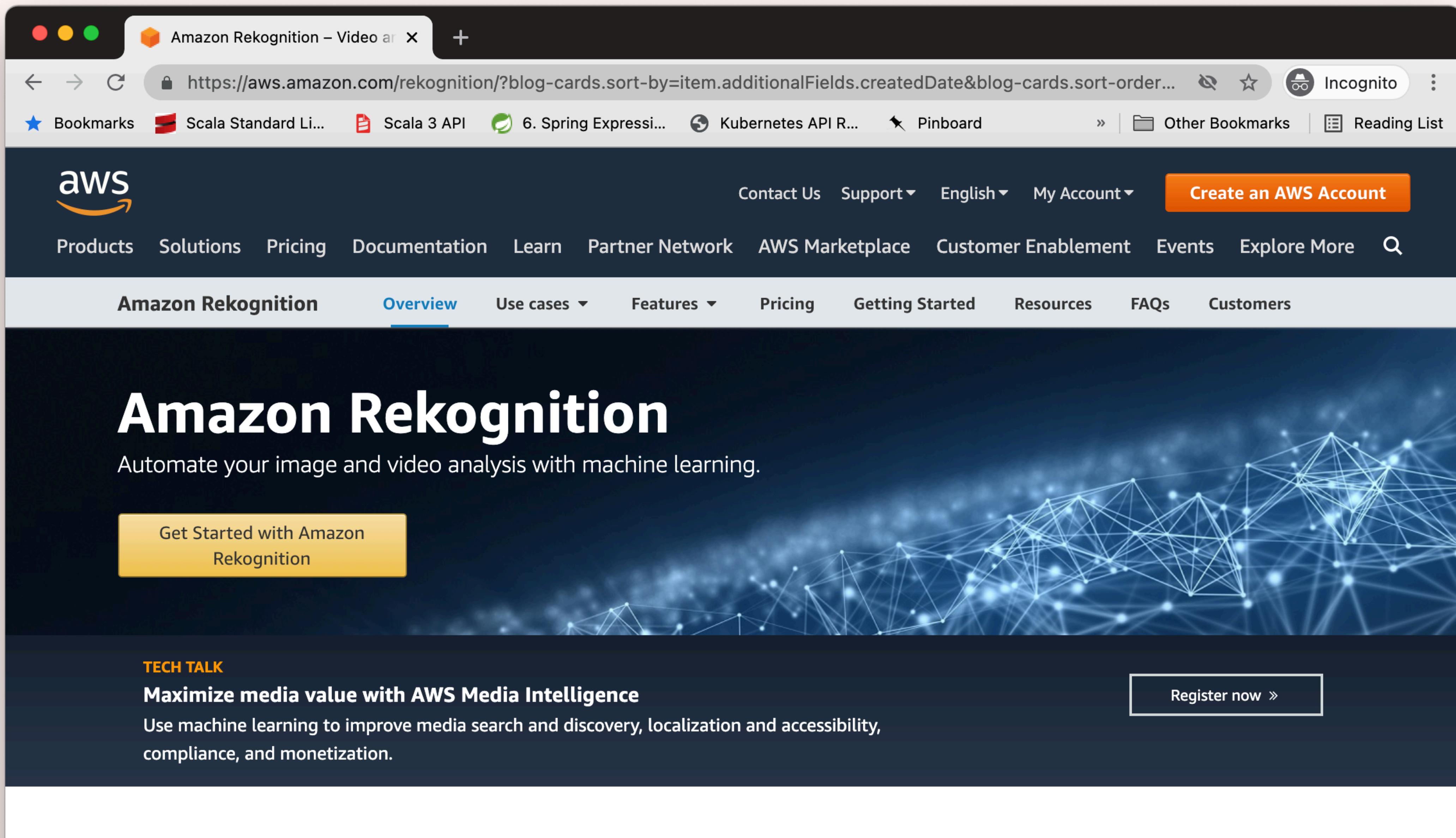
WHY IS THE JS GAME SO STRONG?



Backend	Time (ms)	Speedup
Plain JS	3326	1x
WebGL (Intel Iris Pro)	49	71x
WebGL (GTX 1080)	5	685x
Node.js CPU w/ AVX2	87	39x
Node.js CUDA (GTX 1080)	3	1105x



CLOUD SOLUTIONS



A screenshot of a web browser displaying the Amazon Rekognition landing page. The page has a dark blue header with the AWS logo and navigation links like Products, Solutions, Pricing, Documentation, Learn, Partner Network, AWS Marketplace, Customer Enablement, Events, Explore More, and a search icon. Below the header is a navigation bar with tabs for Amazon Rekognition (selected), Overview, Use cases ▾, Features ▾, Pricing, Getting Started, Resources, FAQs, and Customers. The main content area features a large white title "Amazon Rekognition" and a subtitle "Automate your image and video analysis with machine learning." To the left of the text is a yellow button labeled "Get Started with Amazon Rekognition". The background of the main section is a dark blue gradient with a glowing network graph on the right. At the bottom, there's a "TECH TALK" section titled "Maximize media value with AWS Media Intelligence" with a "Register now >" button, and a footer note about Amazon Rekognition making it easy to add image and video analysis to applications using.

Amazon Rekognition – Video ar X +

https://aws.amazon.com/rekognition/?blog-cards.sort-by=item.additionalFields.createdDate&blog-cards.sort-order... Incognito

Bookmarks Scala Standard Li... Scala 3 API 6. Spring Expressi... Kubernetes API R... Pinboard Other Bookmarks Reading List

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Amazon Rekognition Overview Use cases ▾ Features ▾ Pricing Getting Started Resources FAQs Customers

Amazon Rekognition

Automate your image and video analysis with machine learning.

Get Started with Amazon Rekognition

TECH TALK

Maximize media value with AWS Media Intelligence

Use machine learning to improve media search and discovery, localization and accessibility, compliance, and monetization.

Register now >

Amazon Rekognition makes it easy to add image and video analysis to your applications using

DEMO: AMAZON RECOGNITION

<https://azure.microsoft.com/en-us/free/cognitive-services>

The screenshot shows a web browser window with the URL <https://azure.microsoft.com/en-us/free/cognitive-services> in the address bar. The page has a dark background with white text. At the top, it says "Create personalized, AI-driven experiences with an Azure free account". Below that, it says "Get started with 12 months of free services including Azure Cognitive Services". There is a green button labeled "Start free" and a link "Or buy now >". At the bottom, there is a screenshot of the Microsoft Azure portal interface.

Microsoft Azure

Create personalized, AI-driven experiences with an Azure free account

Get started with 12 months of free services including Azure Cognitive Services

[Start free](#)

[Or buy now >](#)

The screenshot shows the Microsoft Azure portal interface with a blue header bar. The header includes the title "Microsoft Azure (Preview)", a search bar, and a user profile with the email "Tomas@contoso.com". Below the header, there is a section titled "Azure services" with various icons and links for creating resources, managing storage, databases, and more.

Microsoft Azure (Preview)

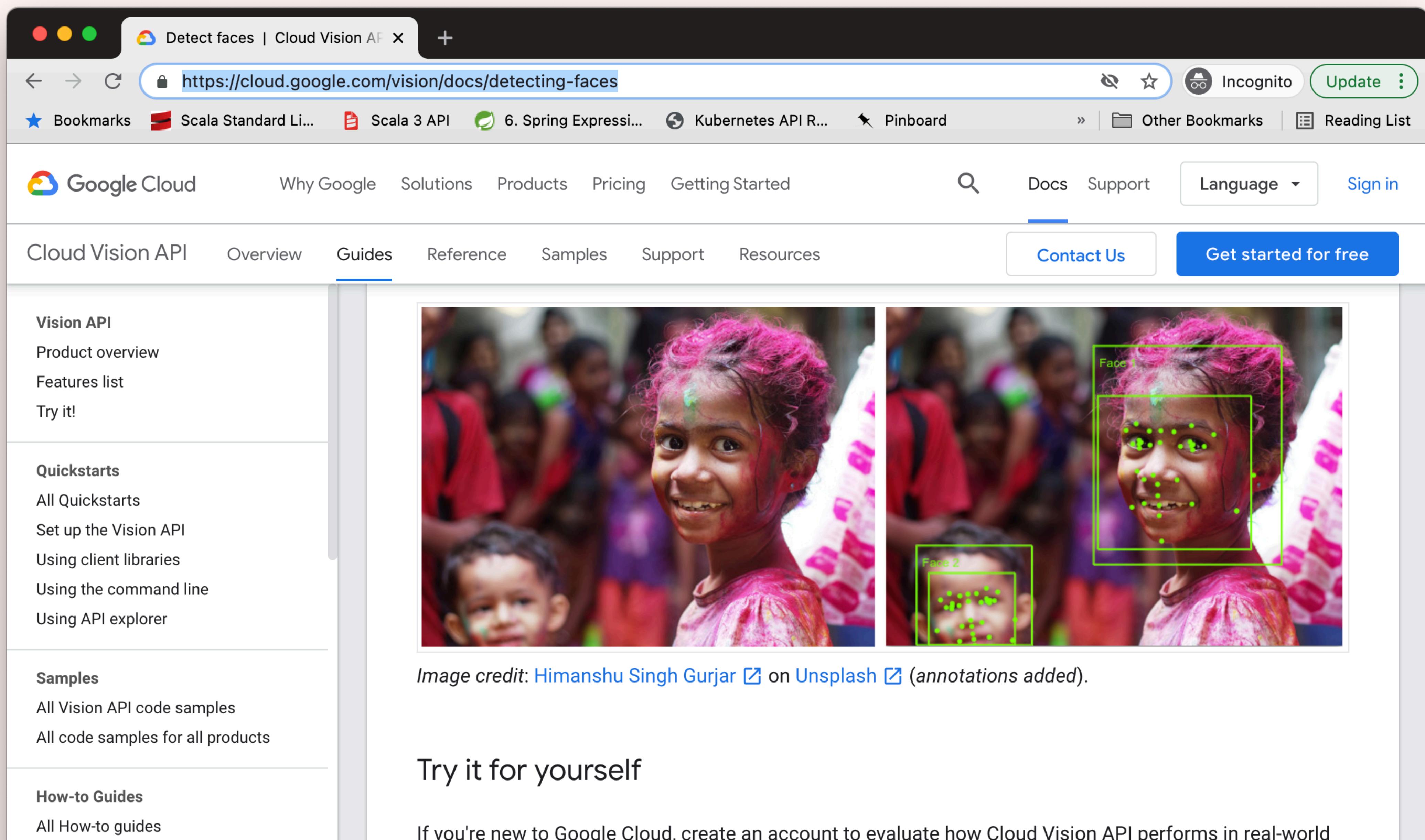
Search resources, services, and docs (G+)

Tomas@contoso.com

Azure services

Create a resource All resources Virtual machines App Services Storage accounts SQL databases Azure Database for PostgreSQL Azure Cosmos DB Kubernetes services More services

<https://cloud.google.com/vision/docs/detecting-faces>



The screenshot shows a web browser window with the URL <https://cloud.google.com/vision/docs/detecting-faces> in the address bar. The page is titled "Detect faces | Cloud Vision API". The main content area displays a photograph of a young girl with pink paint on her face. Two green bounding boxes are drawn around her face, labeled "Face 1" and "Face 2". Numerous small green dots are placed on her face, indicating detected features like eyes, nose, and mouth. To the left of the image, there is a sidebar with navigation links for the Vision API, Quickstarts, Samples, and How-to Guides.

Cloud Vision API

- Overview
- Guides**
- Reference
- Samples
- Support
- Resources

[Contact Us](#) [Get started for free](#)

Vision API

- Product overview
- Features list
- Try it!

Quickstarts

- All Quickstarts
- Set up the Vision API
- Using client libraries
- Using the command line
- Using API explorer

Samples

- All Vision API code samples
- All code samples for all products

How-to Guides

- All How-to guides

Image credit: Himanshu Singh Gurjar [on Unsplash](#) (annotations added).

Try it for yourself

If you're new to Google Cloud, create an account to evaluate how Cloud Vision API performs in real-world

AWESOME IDEAS



Arun Gupta ✅ @arungupta · 42m

...

This tweet comes after unlocking the iPhone with a 😊

Love the combination of [#iOS145](#) and Apple Watch 7.4. This is going to be immensely useful for grocery shopping and any other public place during these [#pandemic](#) [#NewNormal](#) times.



10



According to the Rural School and Community Trust, **25% of school shootings are mass incidents** (4 or more injured or killed), **all mass incidents in elementary schools are committed by intruders**, and **94% of those mass incidents were committed by adults**. By using facial recognition technology to secure access points, schools can immediately identify those who are not authorized to be on campus before they enter buildings. While implementing facial recognition technology may be considered radical, it is ultimately nothing more than a means of amplifying the normal human capability of recognizing who belongs in the community and who does not. It is worth considering this convenient and affordable technology in comparison to other identification systems. For example, name badges can be easily lost or stolen and then used by intruders to trespass onto school grounds.

SCIENCE \ TECH \ ARTIFICIAL INTELLIGENCE

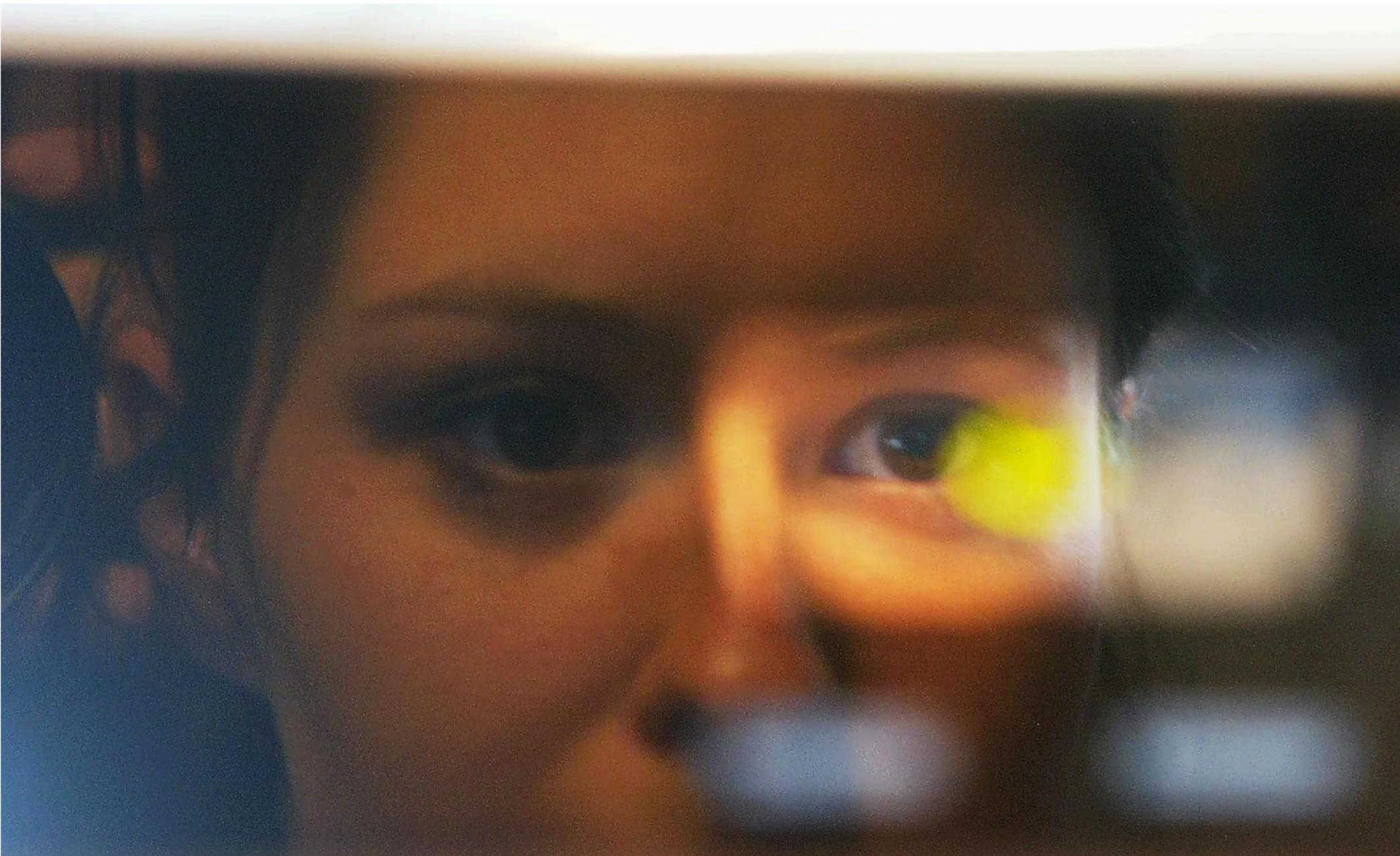
Facial recognition and AI could be used to identify rare genetic disorders

Algorithms could help spot facial features linked to rare conditions

By James Vincent | Jan 15, 2019, 2:11pm EST

If you buy something from a Verge link, Vox Media may earn a commission. See our [ethics statement](#).

f    SHARE



<https://www.theverge.com/2019/1/15/18183779/facial-recognition-ai-algorithms-detect-rare-genetic-disorder-fdna>

POLICIES AND PRIVACY

CITIES BANNING FACIAL RECOGNITION

San Francisco Bans Facial Recognition Technology

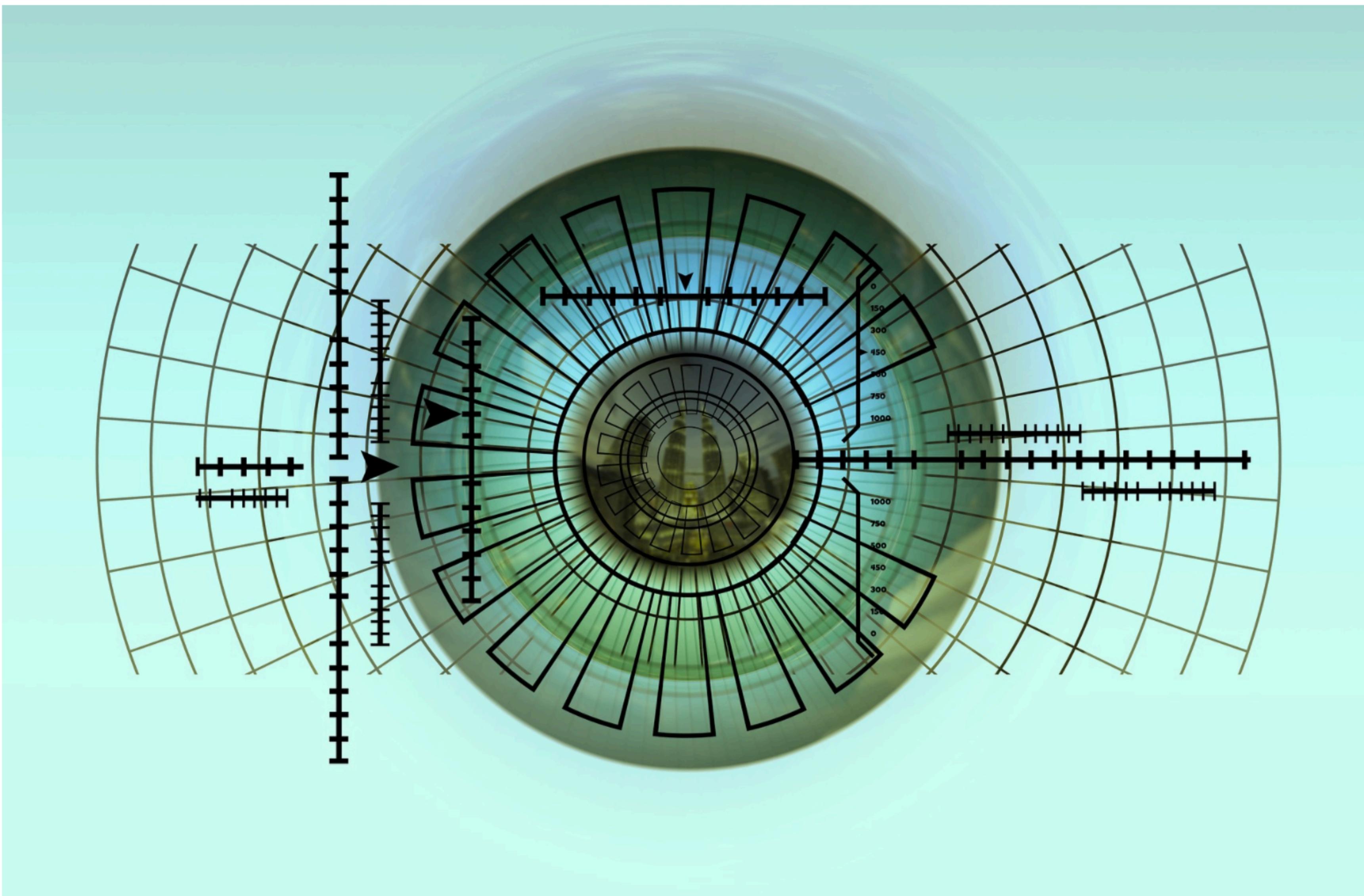


The authorities used the technology to help identify the suspect in the mass shooting at an Annapolis, Md., newspaper last June. But civil liberty groups have expressed unease about the technology's potential abuse by government amid fears that it may shove the United States in the direction of an overly oppressive surveillance state.

<https://www.nytimes.com/2019/05/14/us/facial-recognition-ban-san-francisco.html>

PRIVACY CONCERN

Facial Recognition: When Convenience and Privacy Collide



- Less accuracy and higher bias, particularly when applied to women and minorities, when certain facial recognition technology is outdated.
- Distrust in the security of data privacy and the potential loss of both personally identifiable as well as biometric information due to a data breach.
- Lack of understanding or adequate (and honest) explanation of how and where the technology will be used (e.g. open areas vs. areas deemed private).
- Plain old, general creepiness.

SKIN COLOR CONCERNS

Racial Discrimination in Face Recognition Technology

<https://sitn.hms.harvard.edu/flash/2020/racial-discrimination-in-face-recognition-technology/>

Bookmarks Scala Standard Library Scala 3 API 6. Spring Expressions Kubernetes API Reference Pinboard Other Bookmarks Reading List

Update

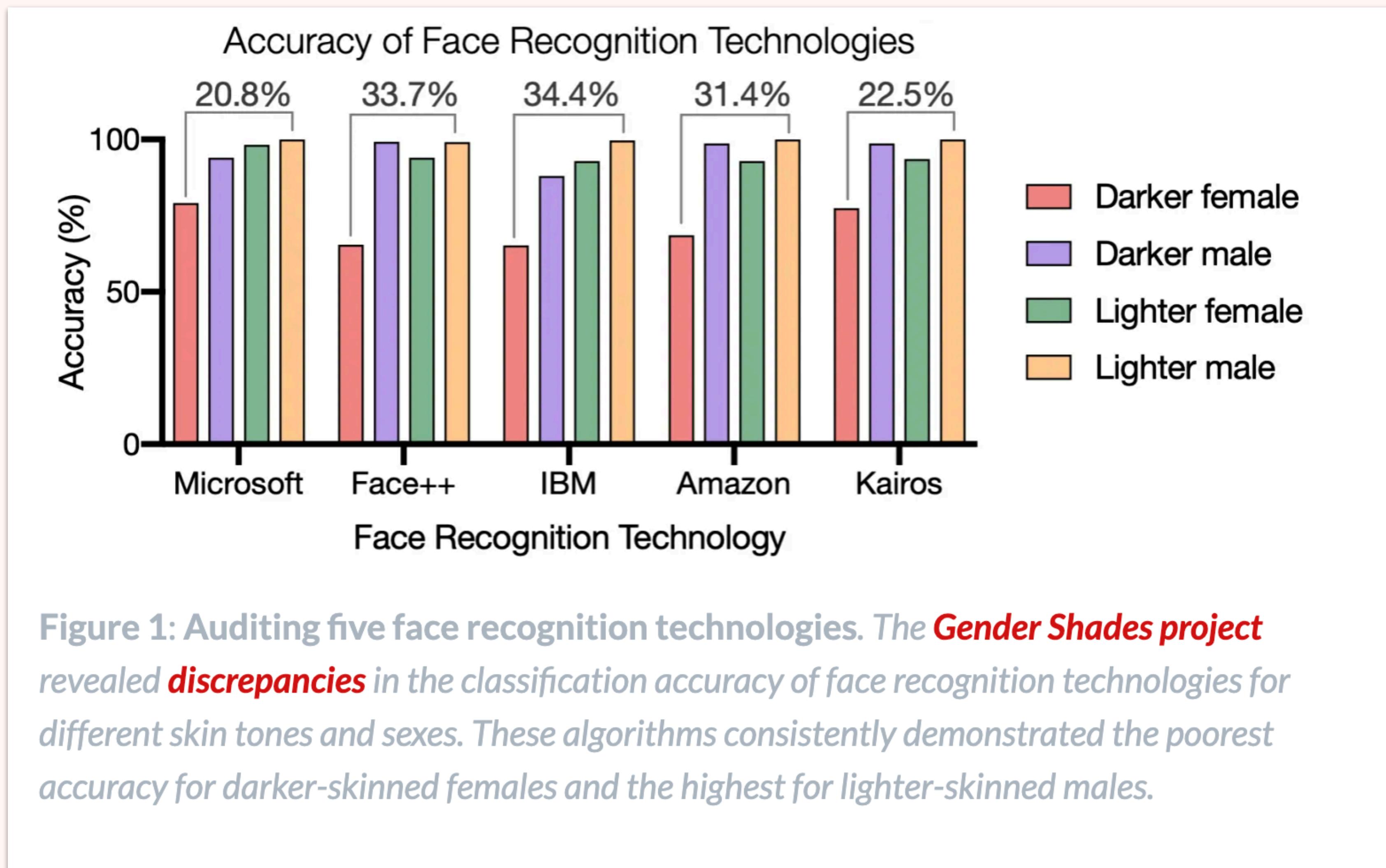
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OCTOBER 24, 2020

BLOG, SCIENCE POLICY, SPECIAL EDITION: SCIENCE POLICY AND SOCIAL JUSTICE

Racial Discrimination in Face Recognition Technology



National Institute of Standards and Technology (NIST) has confirmed these studies, finding that face recognition technologies across 189 algorithms are least accurate on women of color.

<https://sitn.hms.harvard.edu/flash/2020/racial-discrimination-in-face-recognition-technology/>

ALL-AROUND BAD MATCHES

Amazon Rekognition **FALSE MATCHES**



28 current members of Congress

Amazon's Face Recognition Falsely Matched 28 Members of Congress With Mugshots



By [Jacob Snow](#), Technology & Civil Liberties Attorney, ACLU of Northern California
JULY 26, 2018 | 8:00 AM

TAGS: [Face Recognition Technology](#), [Surveillance Technologies](#), [Privacy & Technology](#)

STORAGE OF FACIAL INFORMATION

Proper Storage and Use of Biometric Data

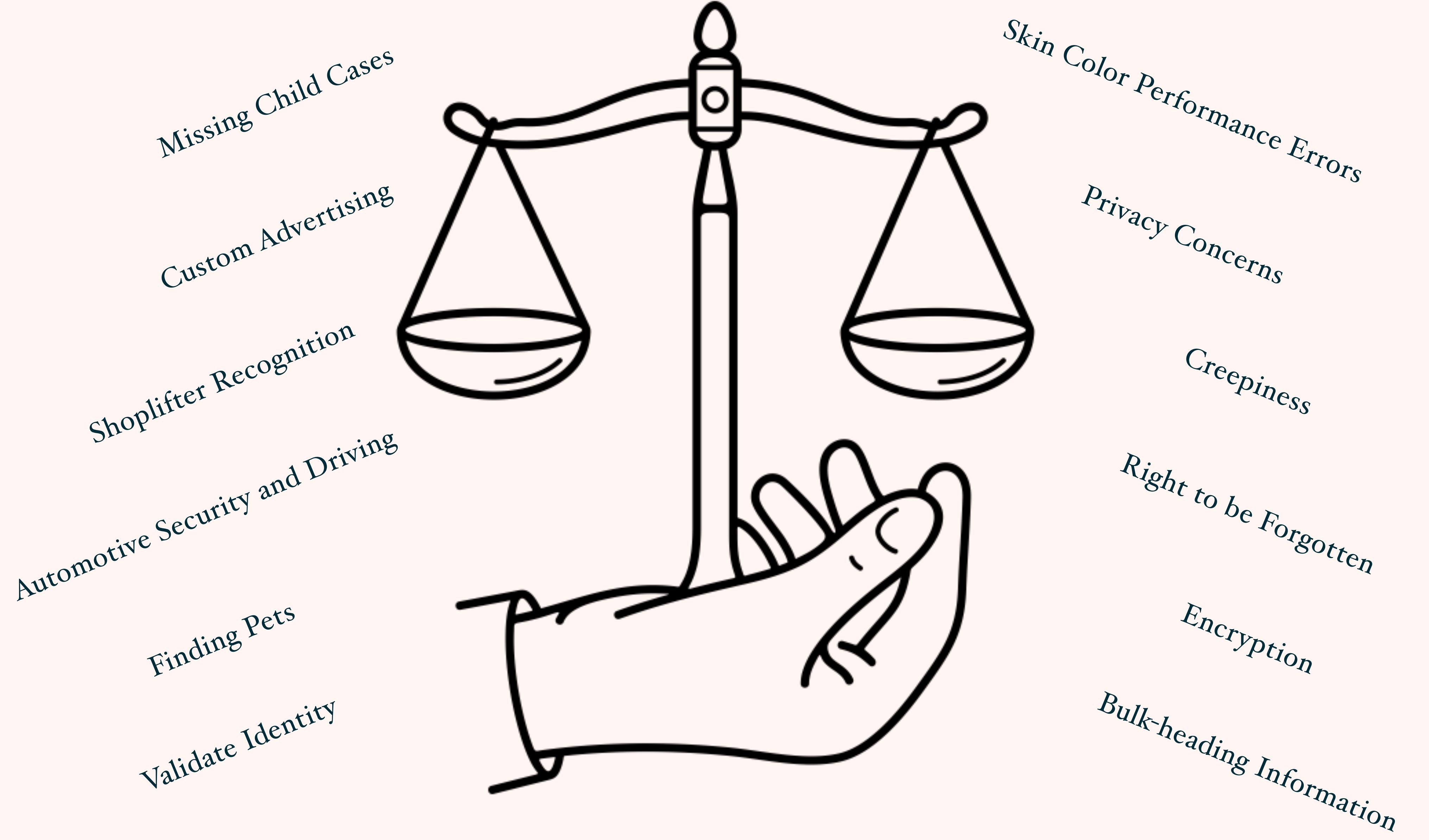
Biometric storage is an important and popular topic. Biometric and personal information that is centrally stored must be encrypted, isolated, and protected.

Biometric data should never be stored with other personally identifiable information such as names, birthdates, etc.

Instead, biometric data should be stored *anonymously* using an opaque key that maps back to the identity. In this way, if the biometric data is ever compromised, it will be useless as there's no way to map it back to a specific individual. Any association of identities (e.g. spouses, parents, children, employers, known associates, etc.) should also be mapped anonymously, using opaque key pairings.

<https://www.forbes.com/sites/ajdellinger/2021/04/03/personal-date-of-533-million-facebook-users-leaks-online/?sh=7f7f03a1717c>

The personally identifying information of more than half a billion Facebook users leaked online Saturday, made available for free on a hacking forum Saturday. The breach, first spotted by cybercrime intelligence firm Hudson Rock, includes full names, Facebook IDs, phone numbers, locations, birth dates, biographies, and email addresses. The user information of more than 533 million accounts were included in the leak and were confirmed by **Business Insider** as being authentic.



FACIAL RECOGNITION CHECKLIST

- **Should Facial Recognition be applied....**
 - **Where civil liberties and basic human rights are stake?**
 - **Allow access to flights, government buildings, schools?**
 - **Illness detection?**
 - **Home and Car Access?**
 - **What is your level of discomfort?**
-



THANK YOU

<http://evolutionnext.com>

Twitter: @dhinojosa