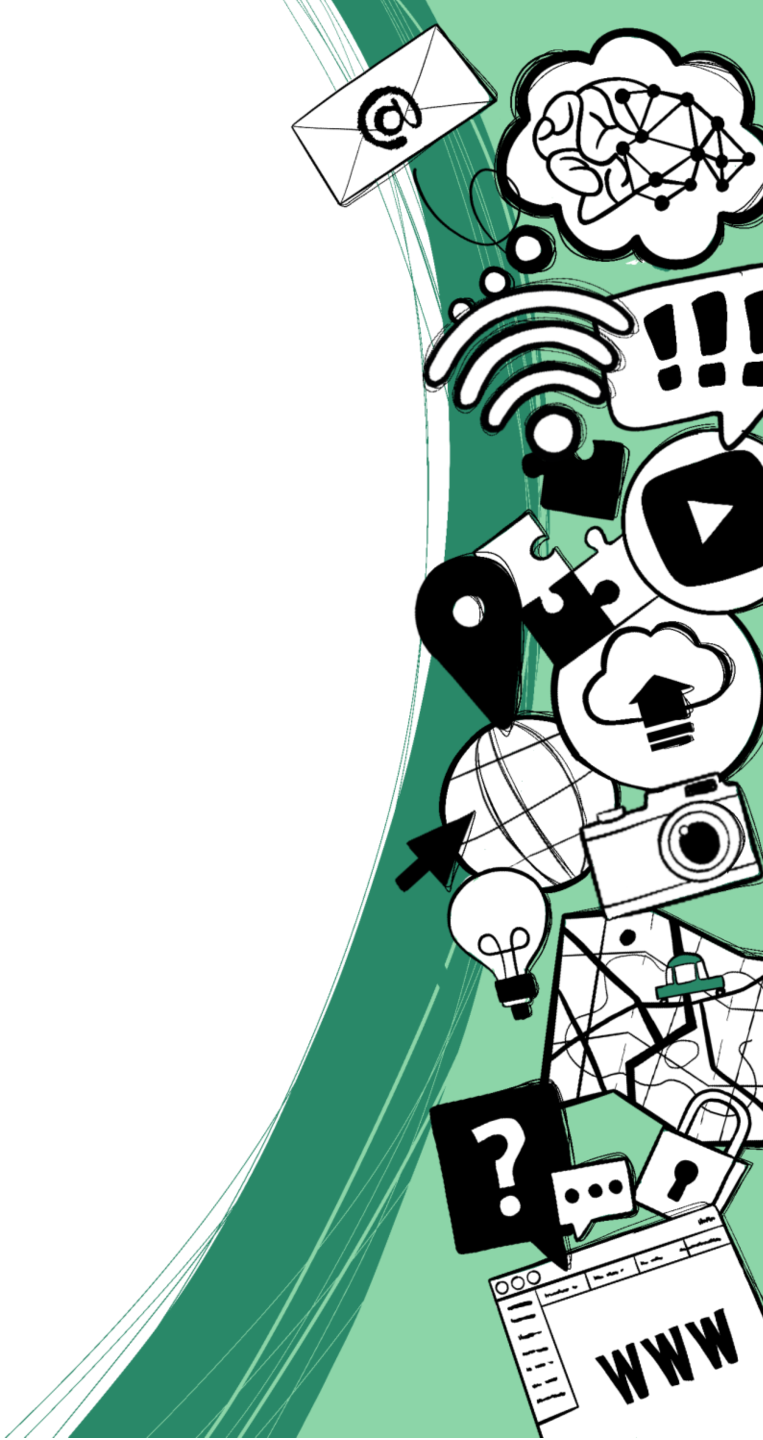
ENARIS

Computer Vision



mobilis
interaktív kiállítási központ

TU Graz

OESTERREICHISCHE COMPUTER GESELLSCHAFT ®
AUSTRIAN COMPUTER SOCIETY

Interreg
Austria-Hungary 2014-2020
European Union – European Regional Development Fund

Computer Vision (CV) Introduction

Visual perception

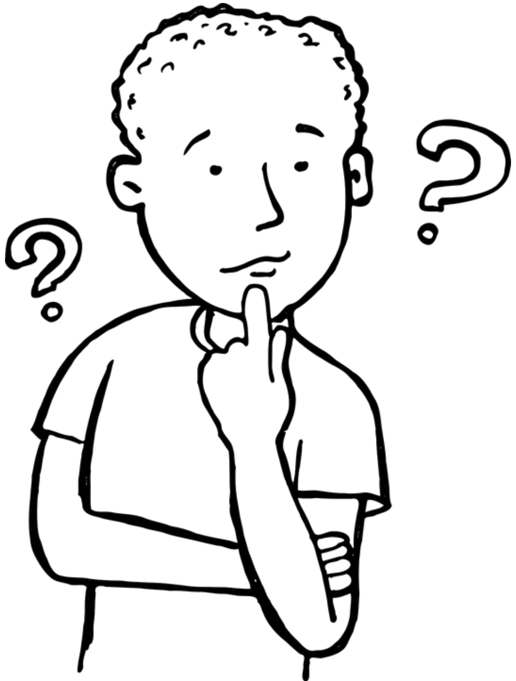
How can people see and recognize things?

We see with our eyes

We process what we see with our brain

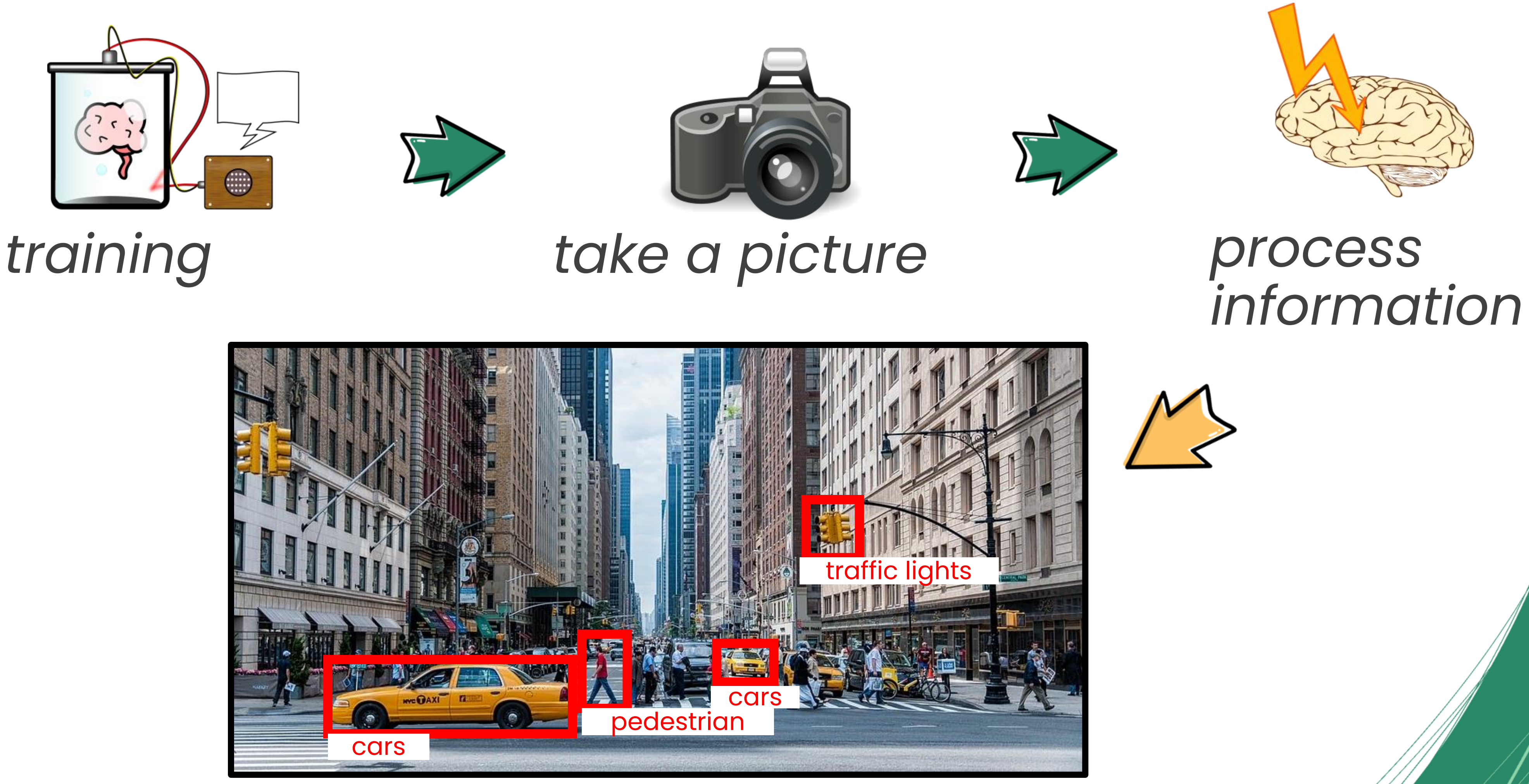
Computer Vision

How is it possible for a computer to see and recognize objects?



Computer Vision

General functionality



training

take a picture

process information

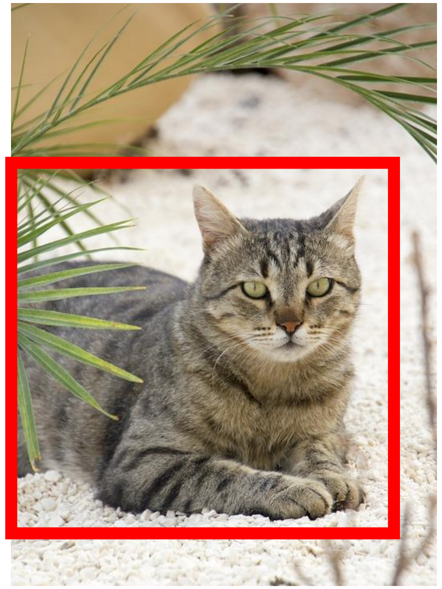
result

Some CV tasks

classification

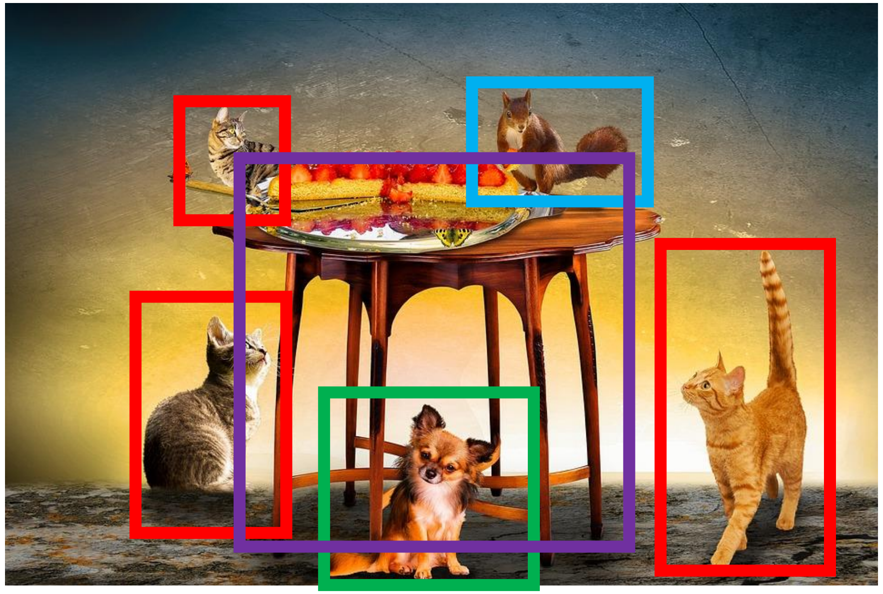
Cat

classification + localization



Cat on position X,Y

object detection

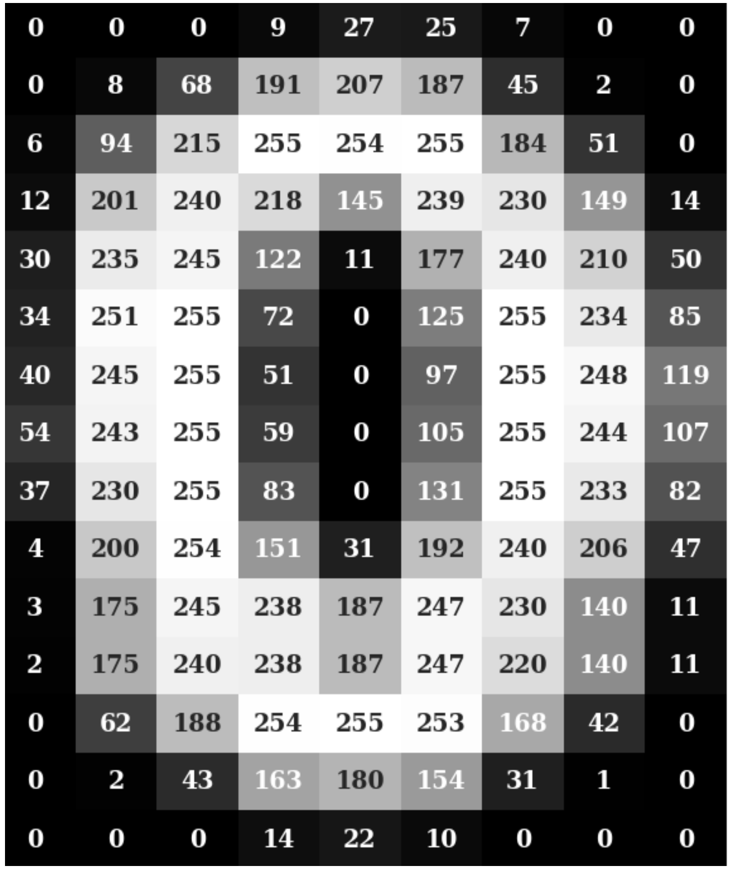


Cat , rat , dog , table

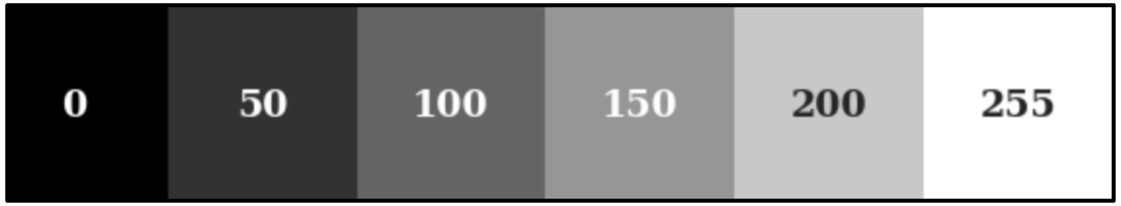
Discover other applications of CV - interactive:
https://aidemos.microsoft.com/computer-vision/recognize

Digital Images – Basics

How are images processed?



0	0	0	9	27	25	7	0	0
0	8	68	191	207	187	45	2	0
6	94	215	255	254	255	184	51	0
12	201	240	218	145	239	230	149	14
30	235	245	122	11	177	240	210	50
34	251	255	72	0	125	255	234	85
40	245	255	51	0	97	255	248	119
54	243	255	59	0	105	255	244	107
37	230	255	83	0	131	255	233	82
4	200	254	151	31	192	240	206	47
3	175	245	238	187	247	230	140	11
2	175	240	238	187	247	220	140	11
0	62	188	254	255	253	168	42	0
0	2	43	163	180	154	31	1	0
0	0	0	14	22	10	0	0	0

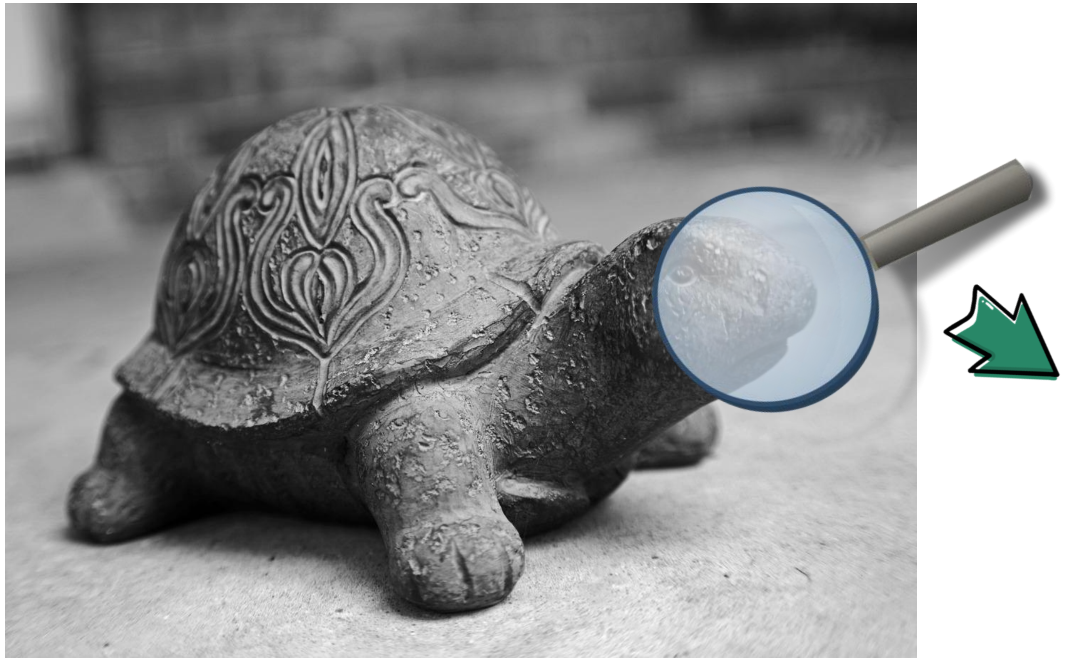


0	50	100	150	200	255

- Images are made up of pixels
- Pixels have color values
- Grayscale images can be saved easily

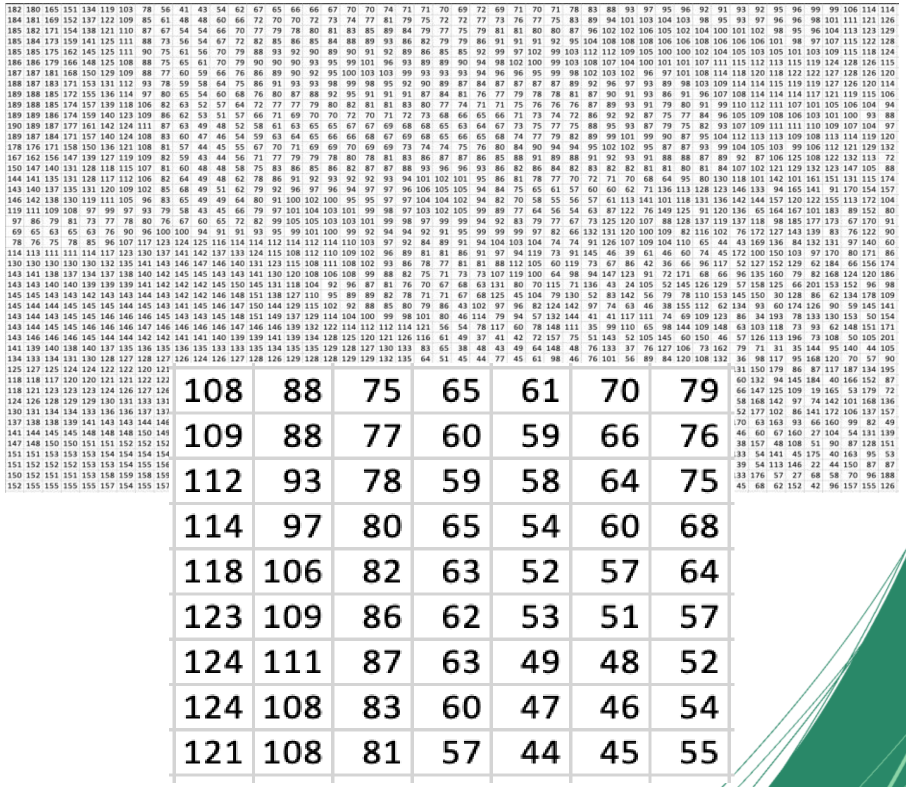
ENARIS

A first comparison

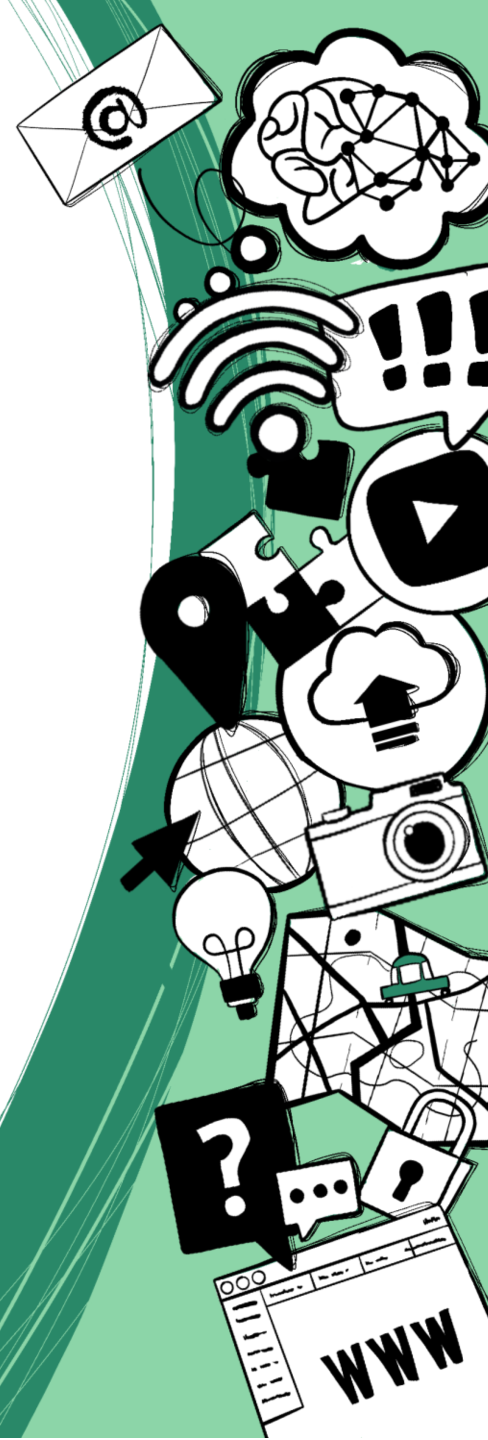


We see

The computer "sees"



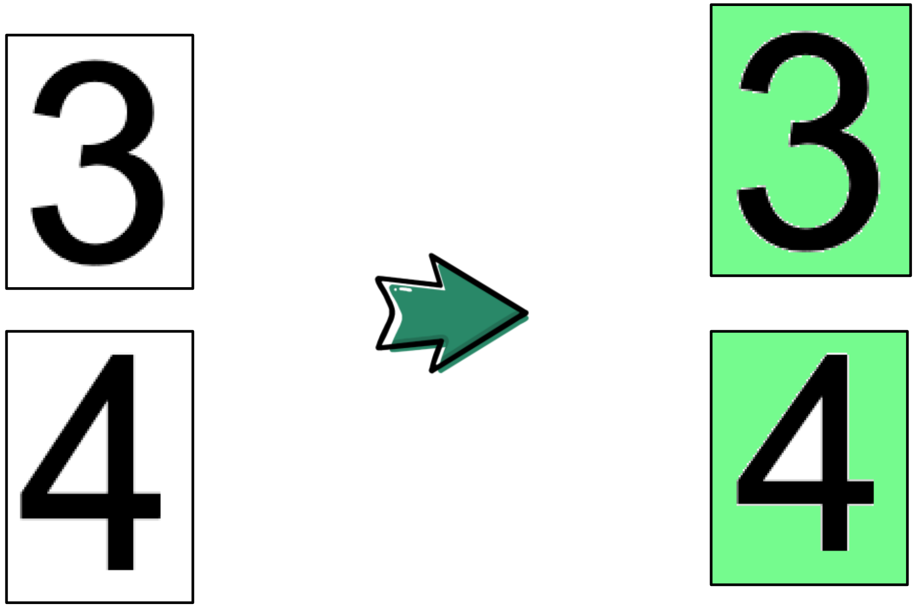
108	88	75	65	61	70	79
109	88	77	60	59	66	76
112	93	78	59	58	64	75
114	97	80	65	54	60	68
118	106	82	63	52	57	64
123	109	86	62	53	51	57
124	111	87	63	49	48	52
124	108	83	60	47	46	54
121	108	81	57	44	45	55



Flood fill algorithm

How could this algorithm work?

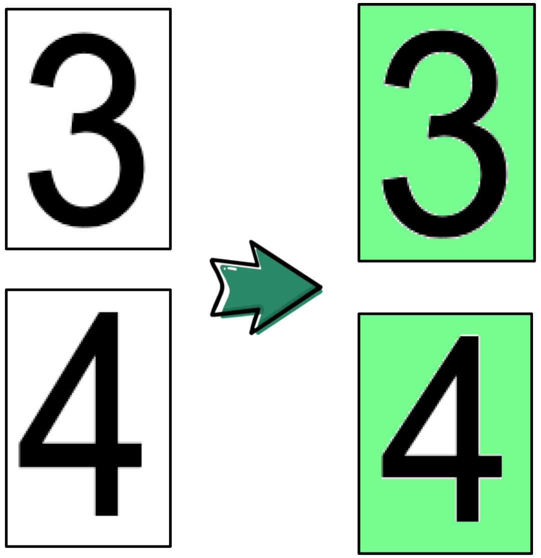
Write down the individual steps

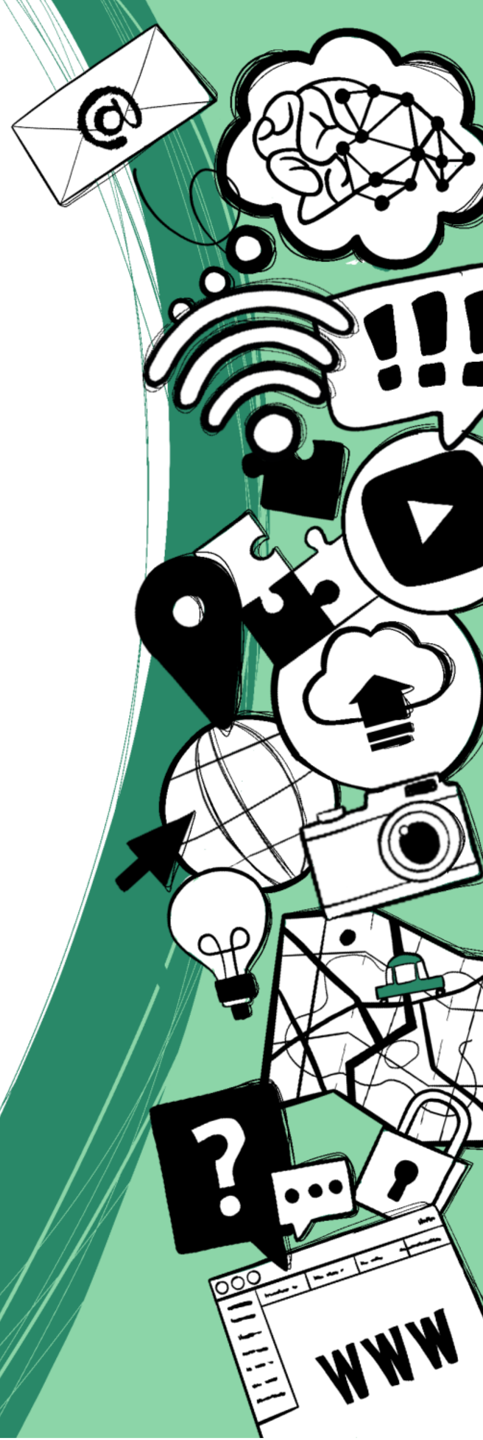


Flood fill algorithm

How could this algorithm work?

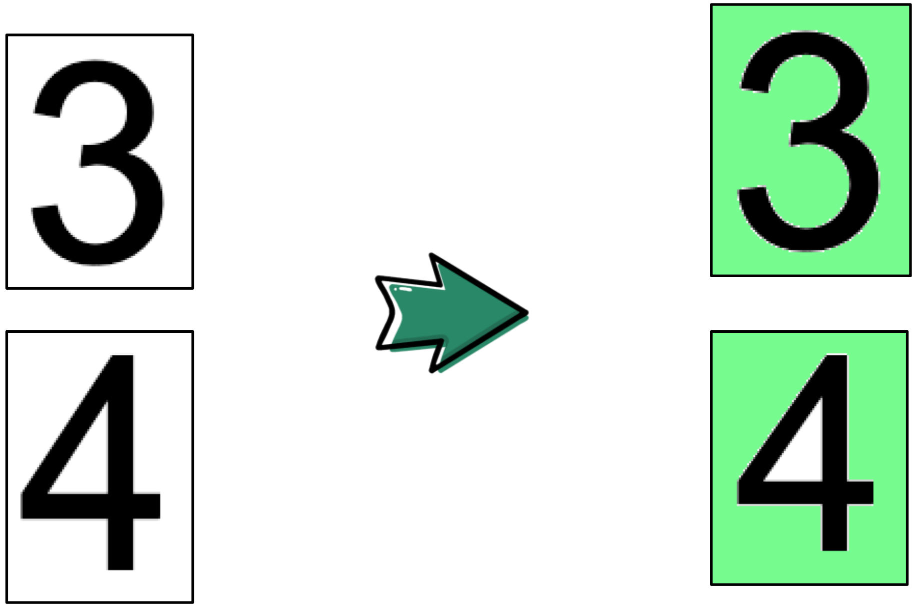
- Take two colors (background and font color)
- Place the brush on a starting point
- Keep painting until the point under the brush has a different color than the background
- When everything is painted, check how much of the brush color was used





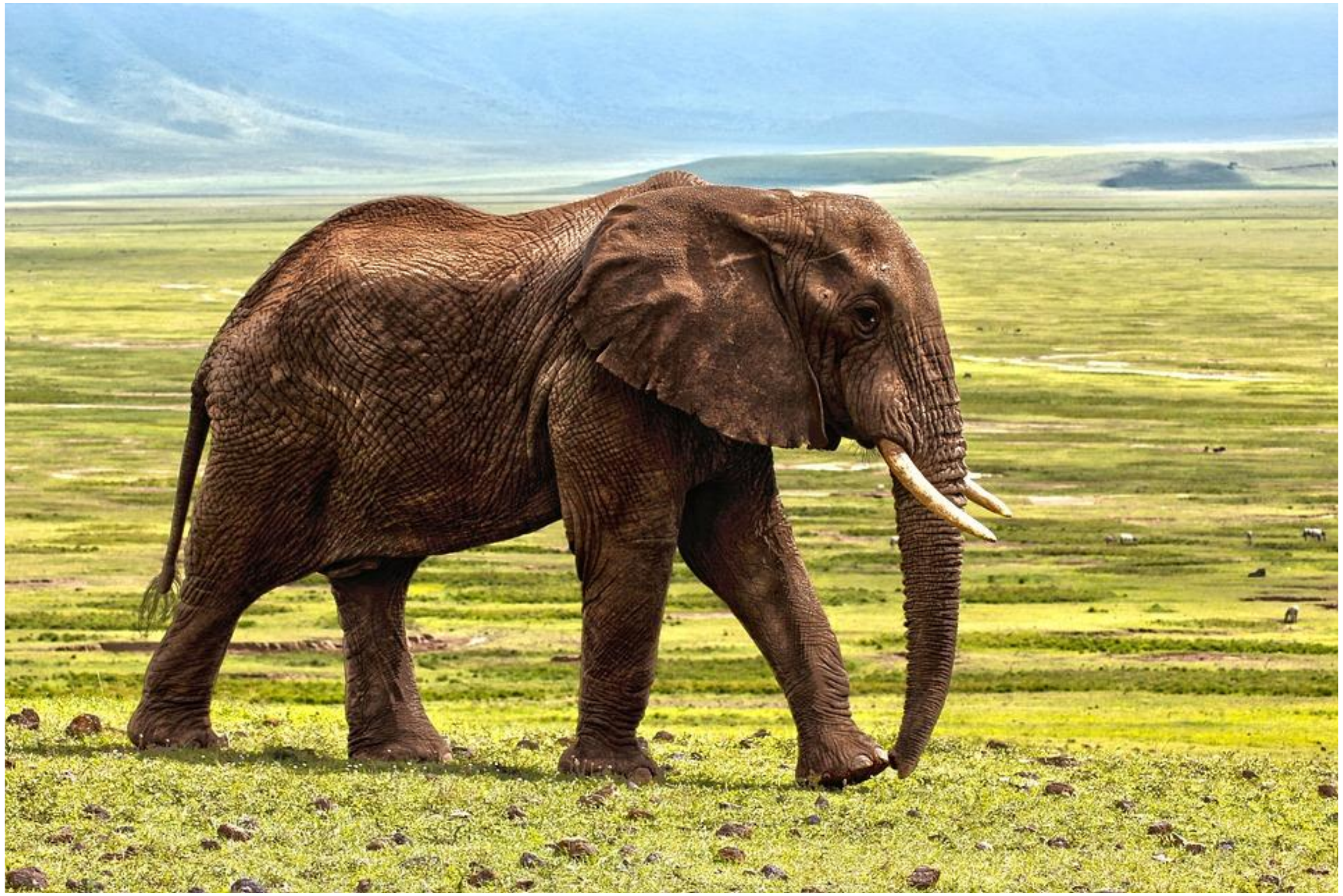
Flood fill algorithm

What problems could arise?



Classic CV Algorithms

Qhat do you see



… and now?

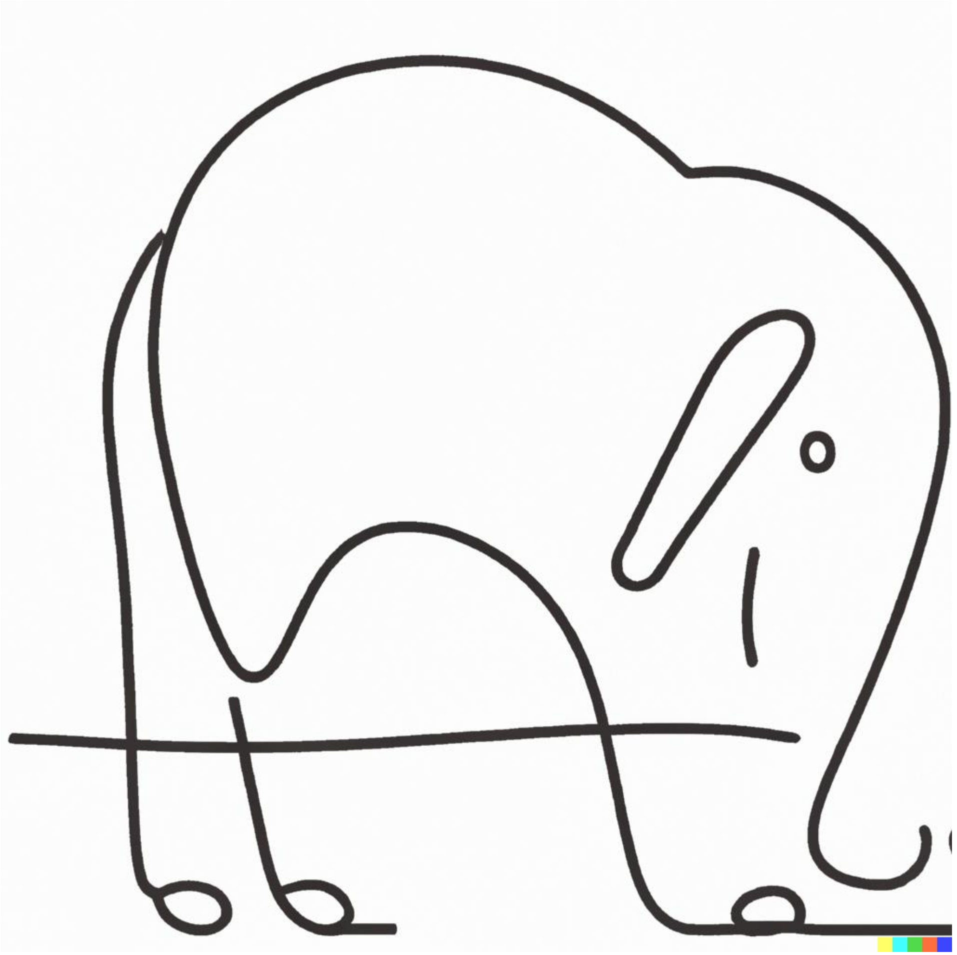
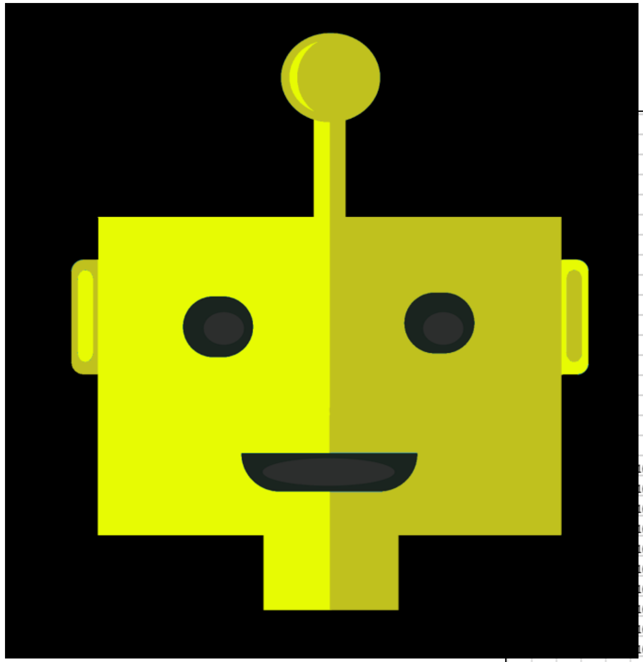
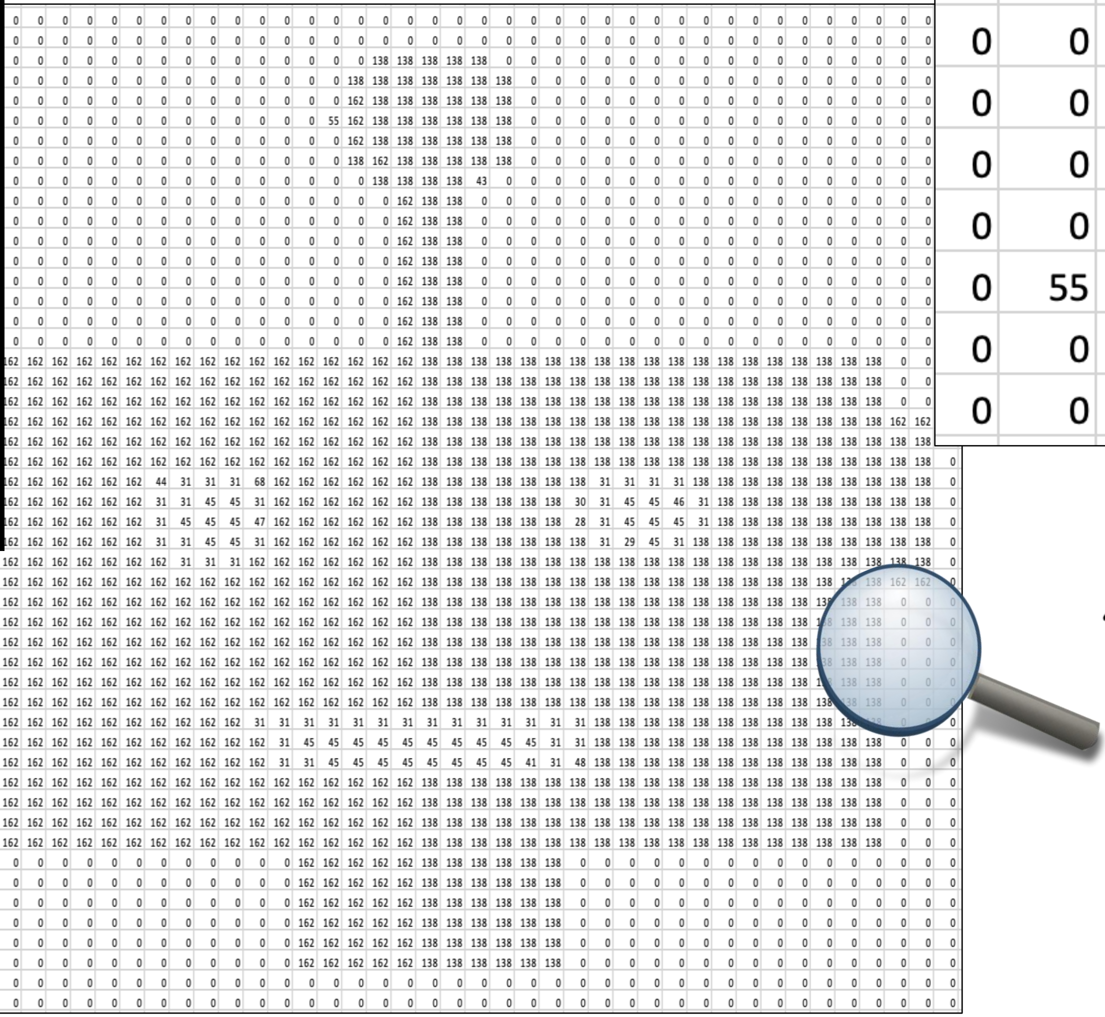


Image created with https://openai.com/dall-e-2/

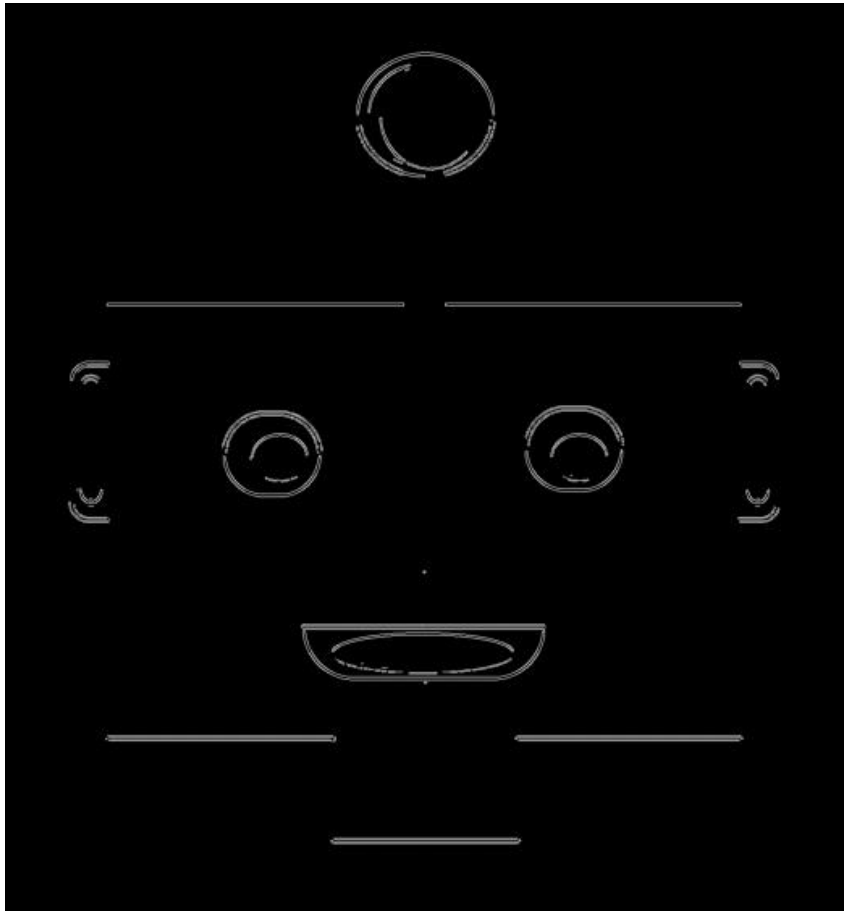
Edge detection algorithm

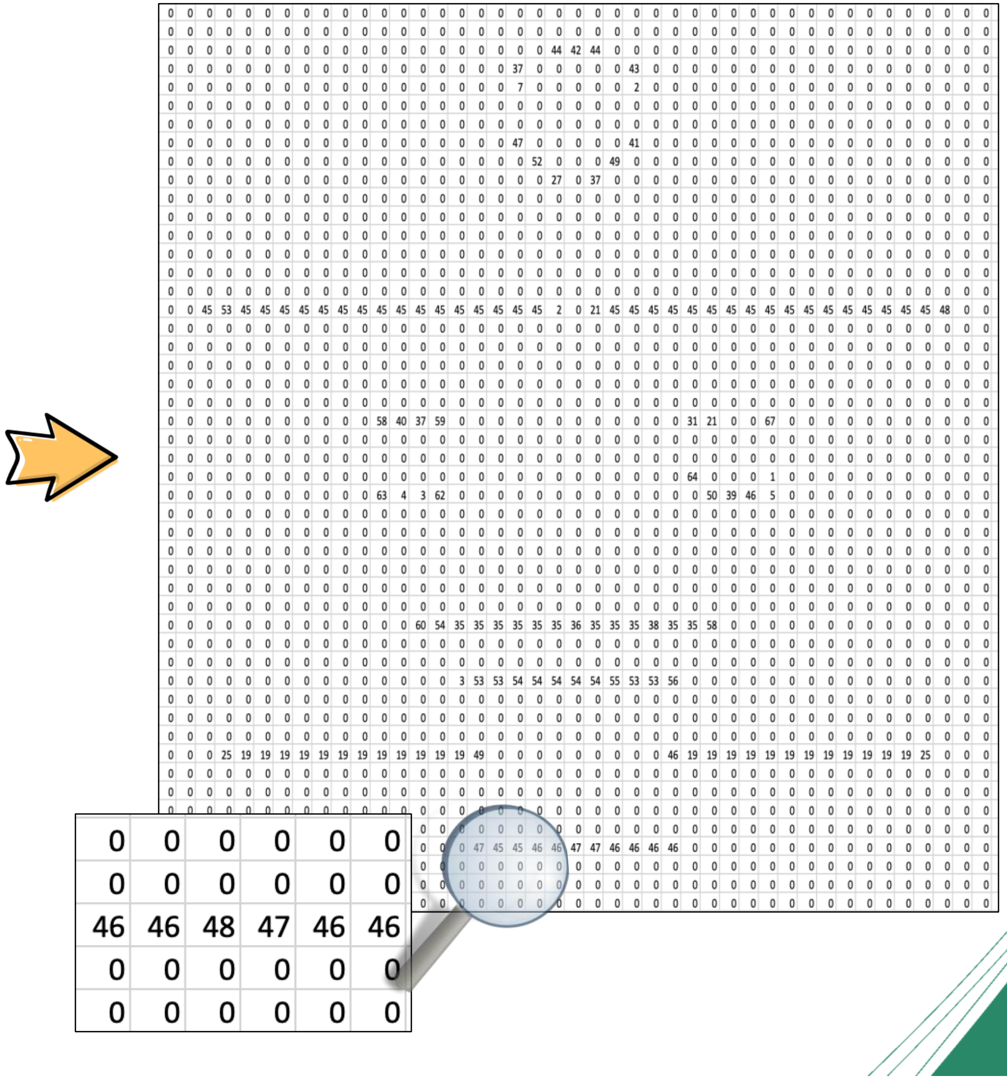




0	0	0	0	0
0	0	0	0	0
0	0	0	138	138
0	0	138	138	138
0	0	162	138	138
0	55	162	138	138
0	0	162	138	138
0	0	138	162	138

Horizontal Edges





0	0	0	0	0	0
0	0	0	0	0	0
46	46	48	47	46	46
0	0	0	0	0	0
0	0	0	0	0	0

Calculate horizontal edges

	A	B	C	D
a	255	255	255	255
b	234	239	234	241
c	40	0	8th	98
i.e	0	0	4	0

calculation rules

Aa - Ab

Ba - Bb

Ca – Cb

Da – Db

…

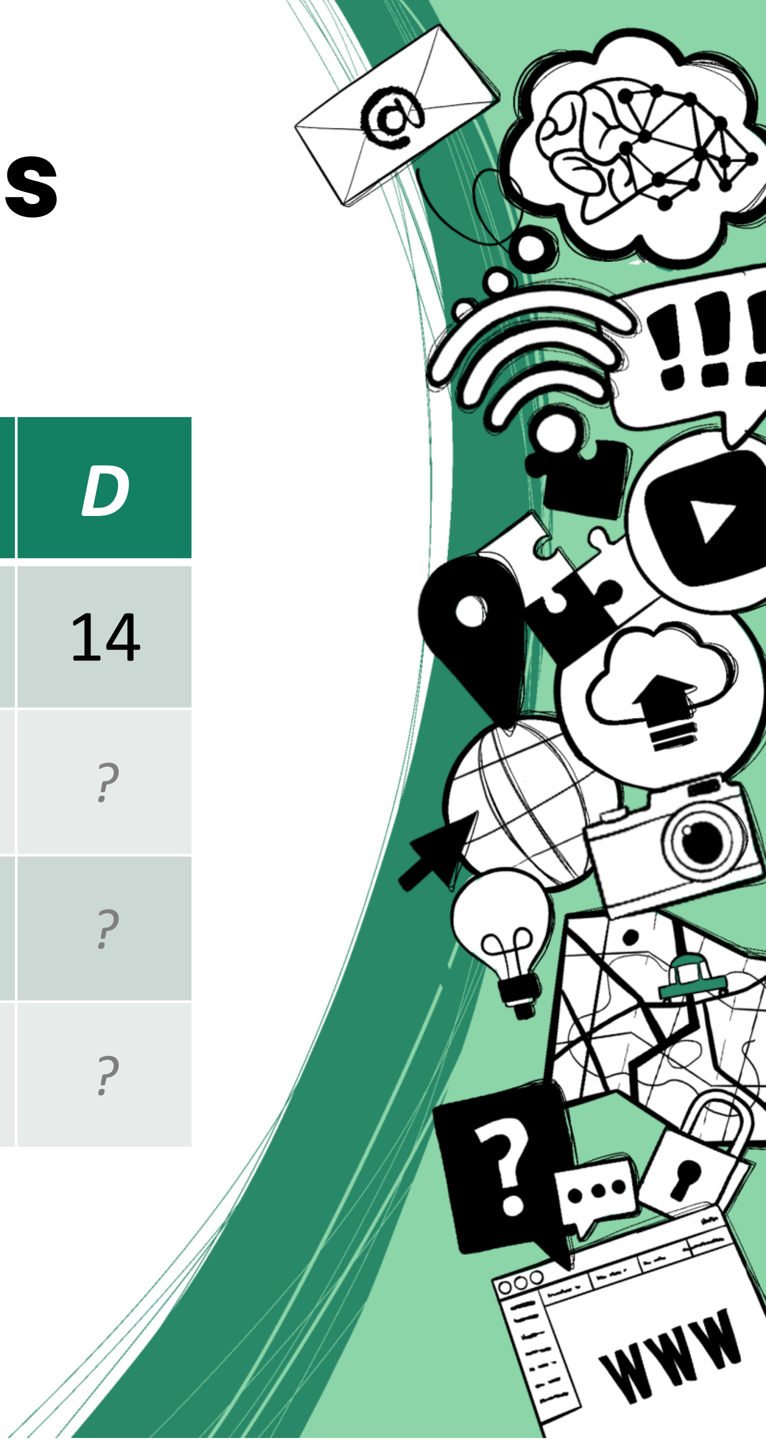
Calculate horizontal edges

	A	B	C	D
a	255	255	255	255
b	234	239	234	241
c	40	0	8th	98
i.e	0	0	4	0

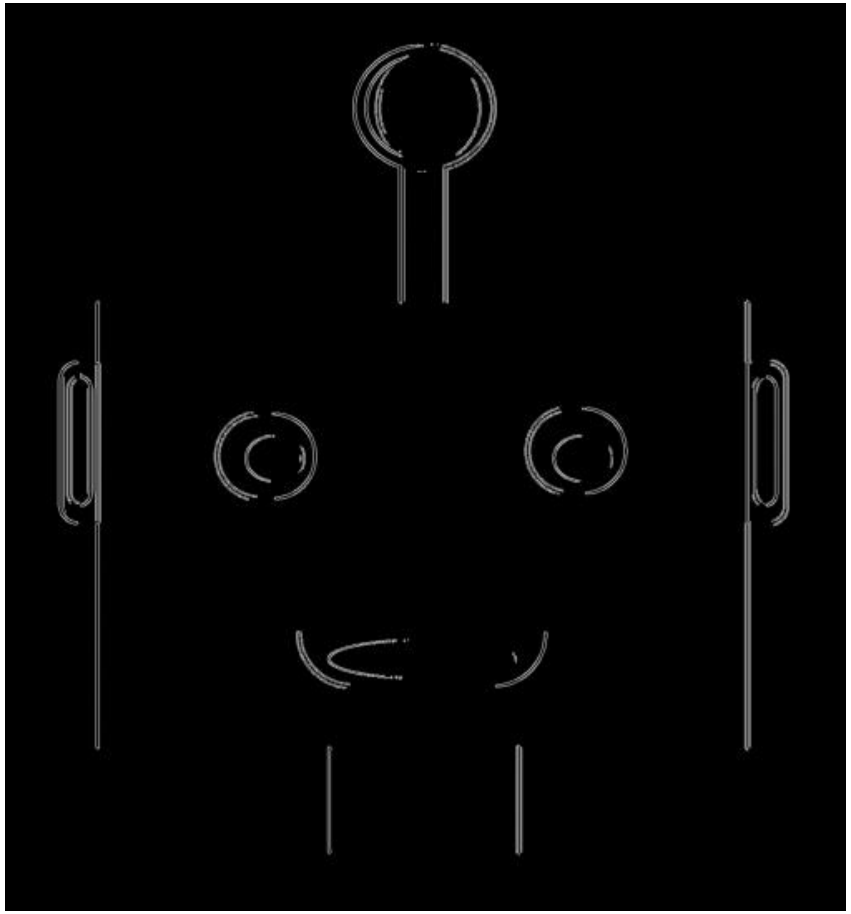
	A	B	C	D
a	21	16	21	14
b	194	?	?	?
c	?	?	?	?
i.e	?	?	?	?

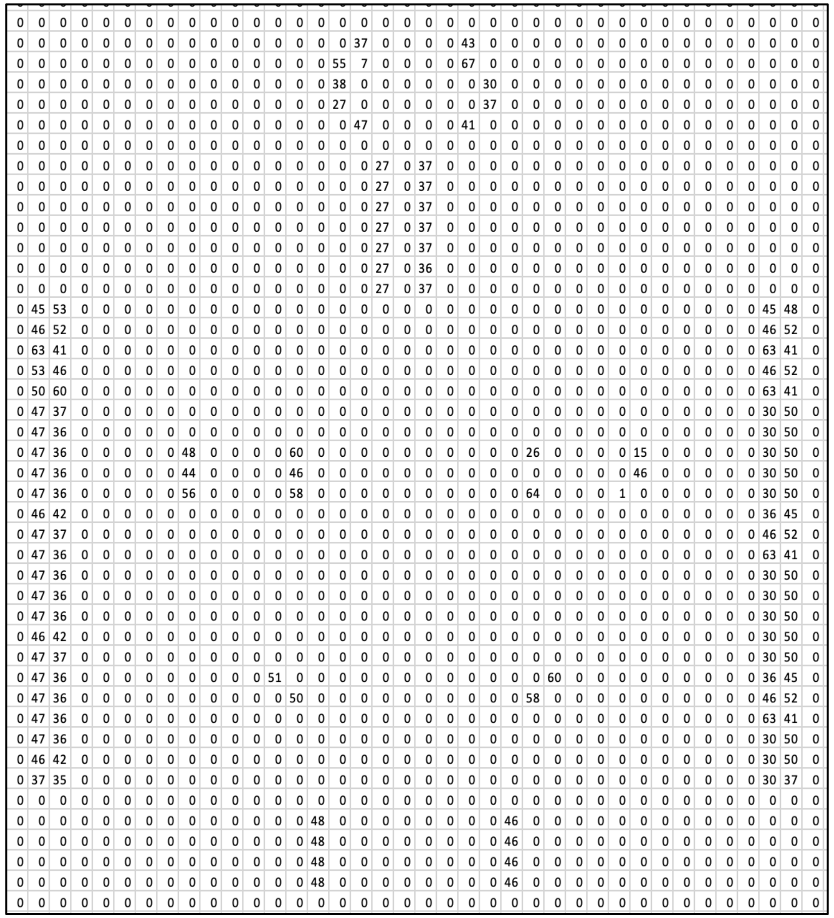
Ab − Ac = 234 − 40 ➔ 194

Aa – Ab
Ba – Bb
Ca – Cb
Da – Db



Vertical edges





0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	0	0	0	0	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	7	0	0	0	0	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	0	0	0	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	0	0	0	0	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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0	45	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	48	0
0	46	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	52	0
0	63	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	41	0
0	53	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	52	0
0	50	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	41	0
0	47	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	50	0
0	47	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	50	0
0	47	36	0	0	0	0	0	48	0	0	0	0	60	0	0	0	0	0	0	0	0	0	0	26	0	0	0	0	15	0	0	0	0	0	30	50	0
0	47	36	0	0	0	0	0	44	0	0	0	0	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	0	0	0	0	0	30	50	0
0	47	36	0	0	0	0	0	56	0	0	0	0	58	0	0	0	0	0	0	0	0	0	0	64	0	0	0	1	0	0	0	0	0	0	30	50	0
0	46	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	45	0
0	47	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	52	0
0	47	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	41	0
0	47	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	50	0
0	47	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	50	0
0	47	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	50	0
0	46	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	50	0
0	47	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	50	0
0	47	36	0	0	0	0	0	0	0	0	0	51	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0	0	0	36	45	0
0	47	36	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	58	0	0	0	0	0	0	0	0	0	0	46	52	0
0	47	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	41	0
0	47	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	50	0
0	46	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	50	0
0	37	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	37	0
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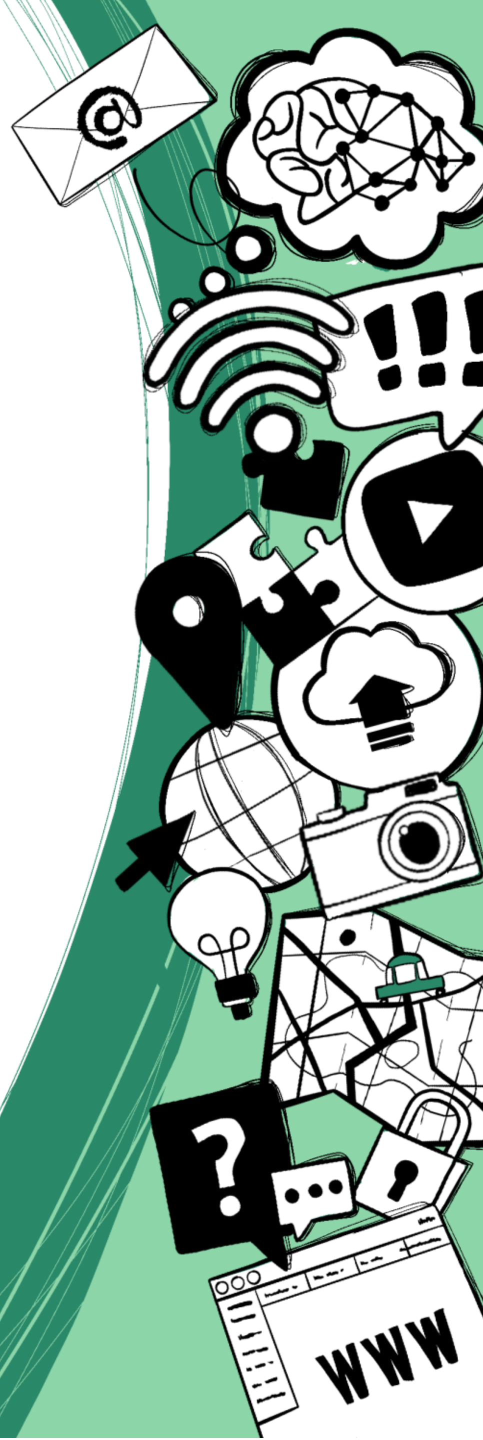
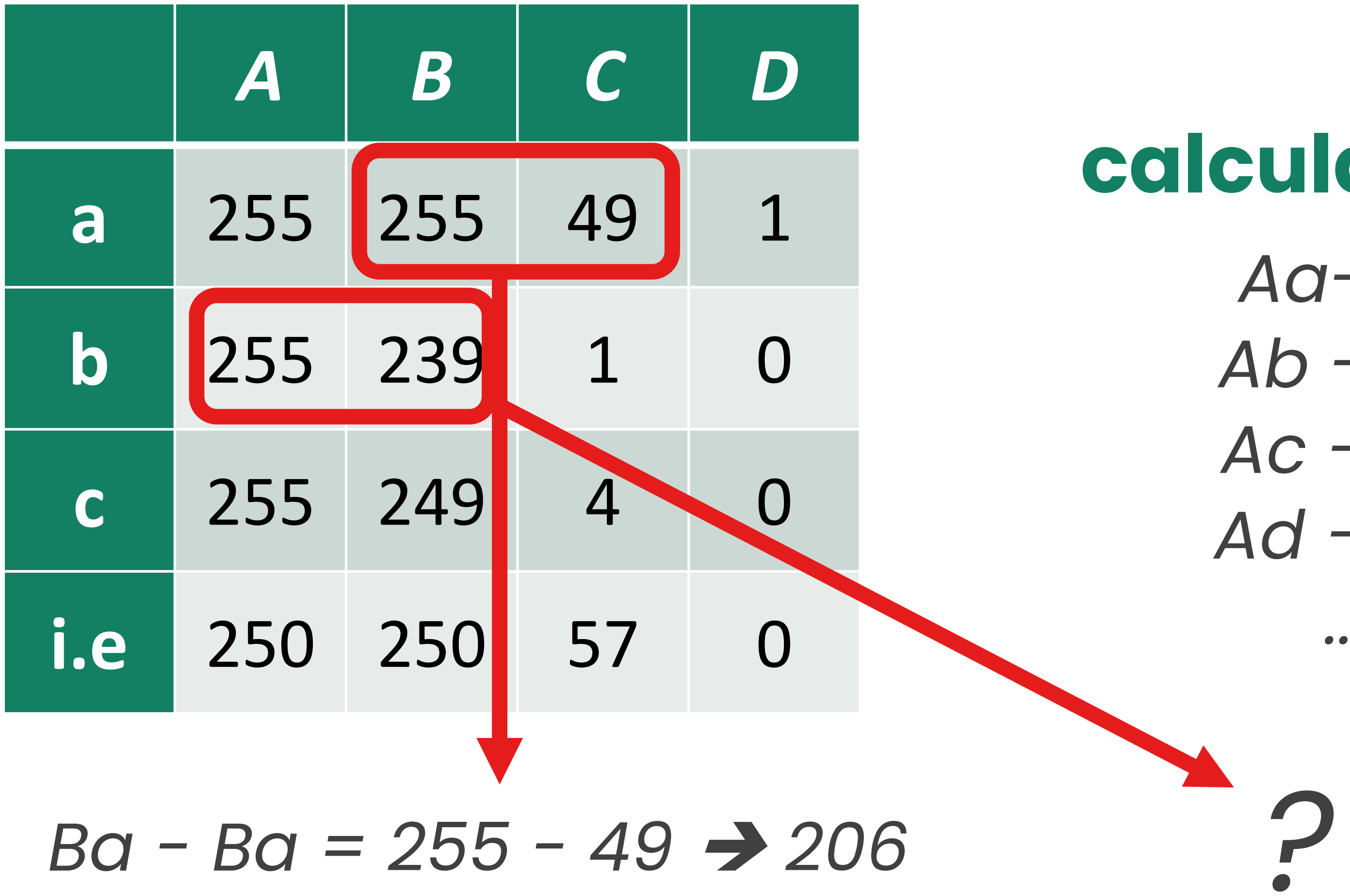
0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



Calculate vertical edges



	A	B	C	D
a	255	255	49	1
b	255	239	1	0
c	255	249	4	0
i.e	250	250	57	0

Ba - Ba = 255 - 49 ➔ 206

?

calculation rules

Aa-Ba

Ab - Ba

Ac - Bb

Ad – Bd

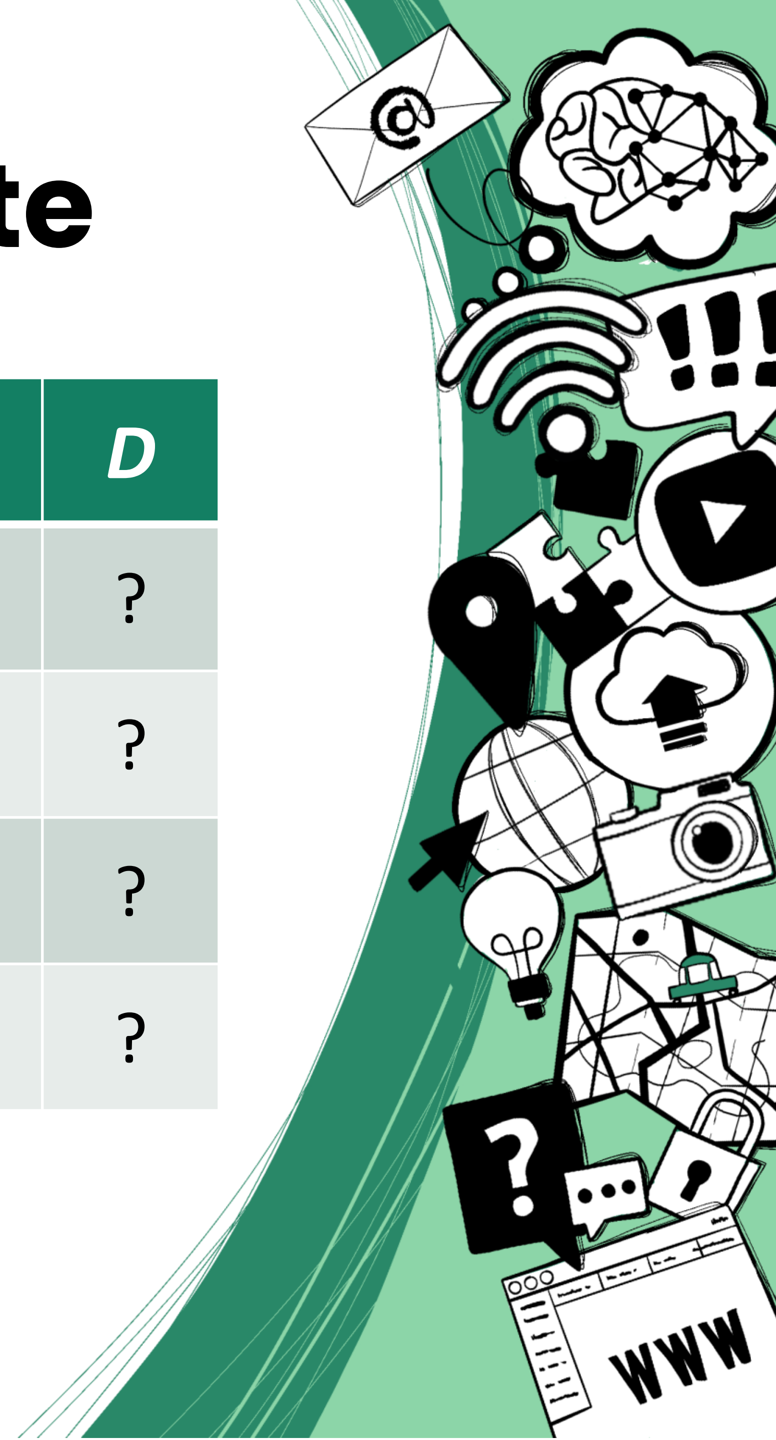
…

vertical edge to calculate

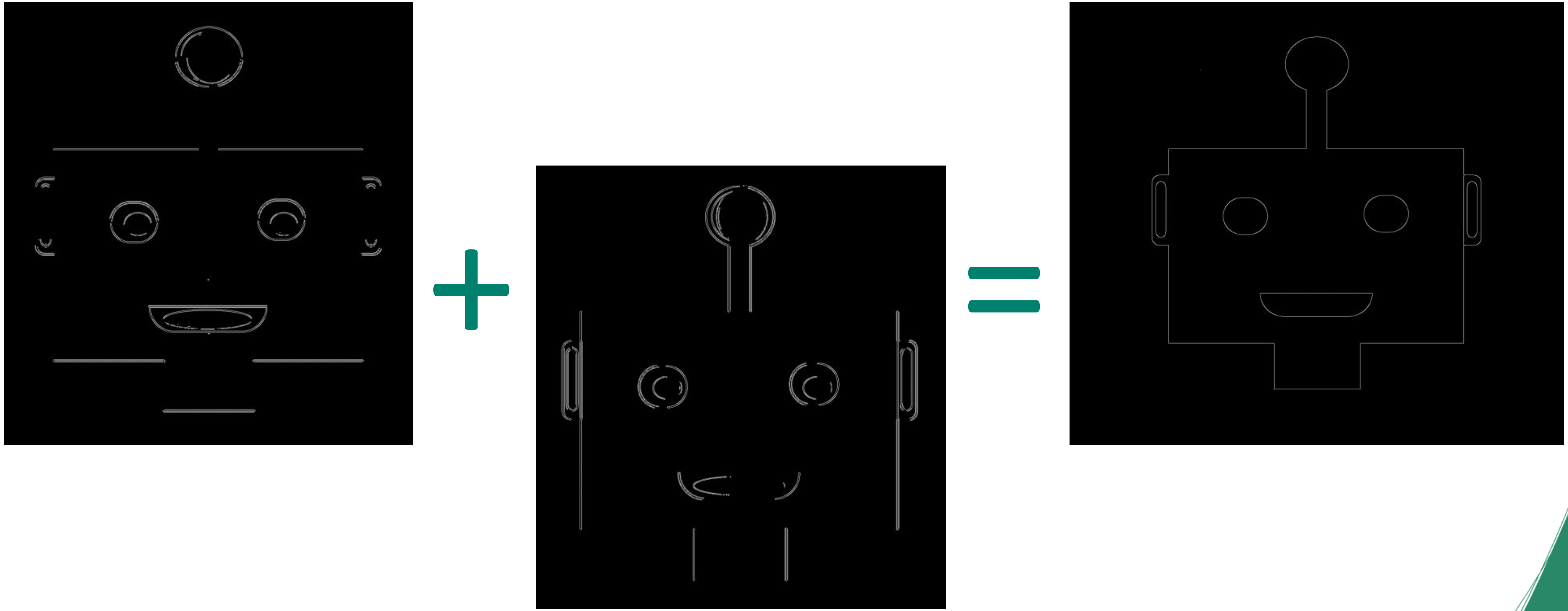
	A	B	C	D
a	255	255	49	1
b	255	239	1	0
c	255	249	4	0
i.e	250	250	57	0

	A	B	C	D
a	0	206	?	?
b	16	?	?	?
c	6	?	?	?
i.e	0	?	?	?

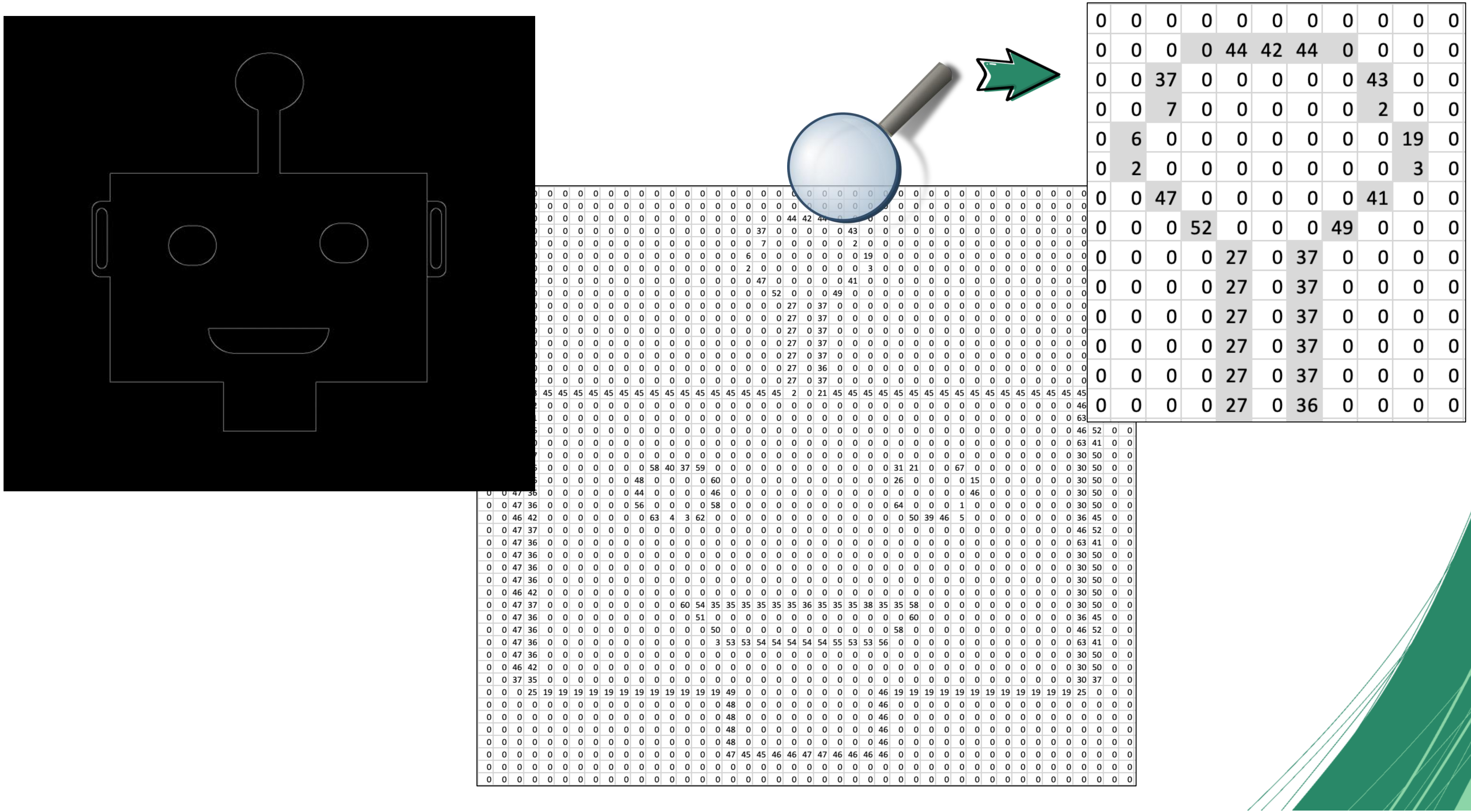
Aa−Ba
Ab − Ba
Ac − Bb
Ad − Bd



Combination of edges

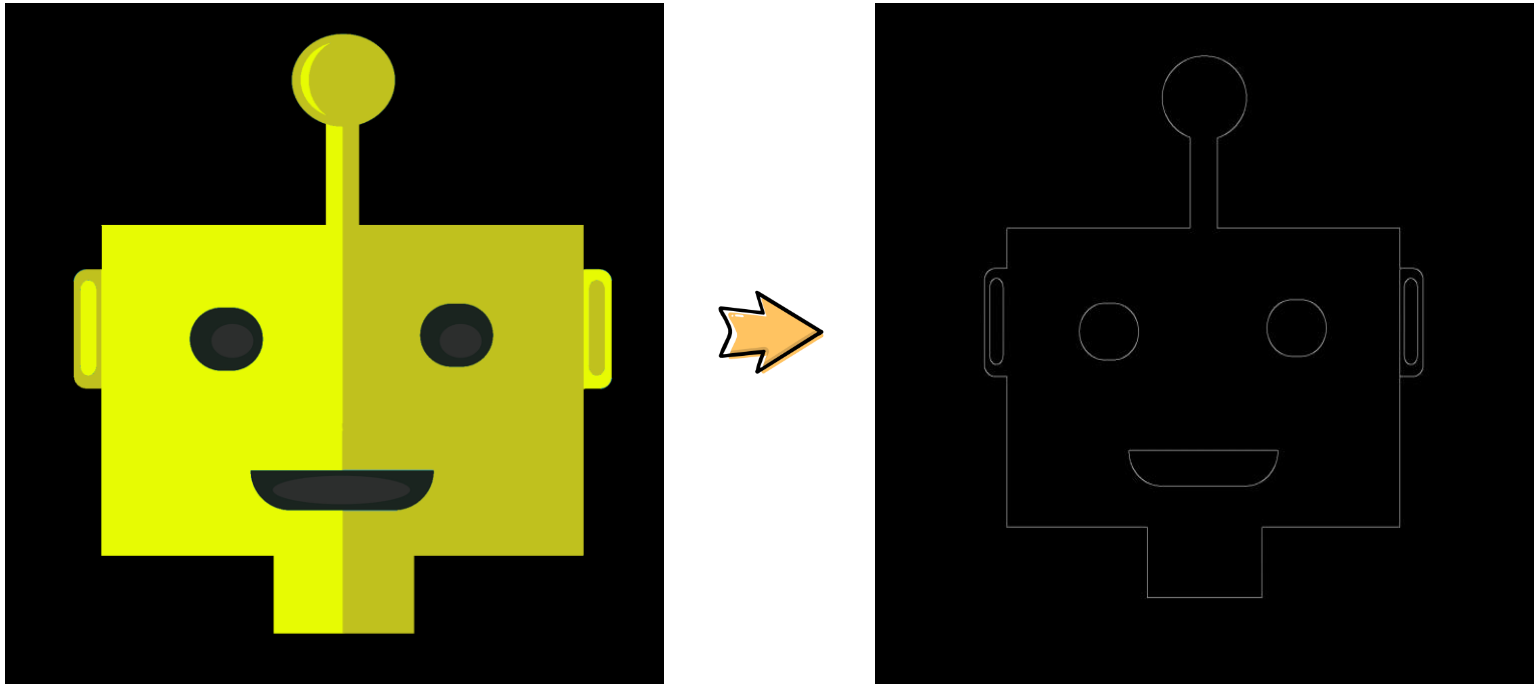


Combining the Edges

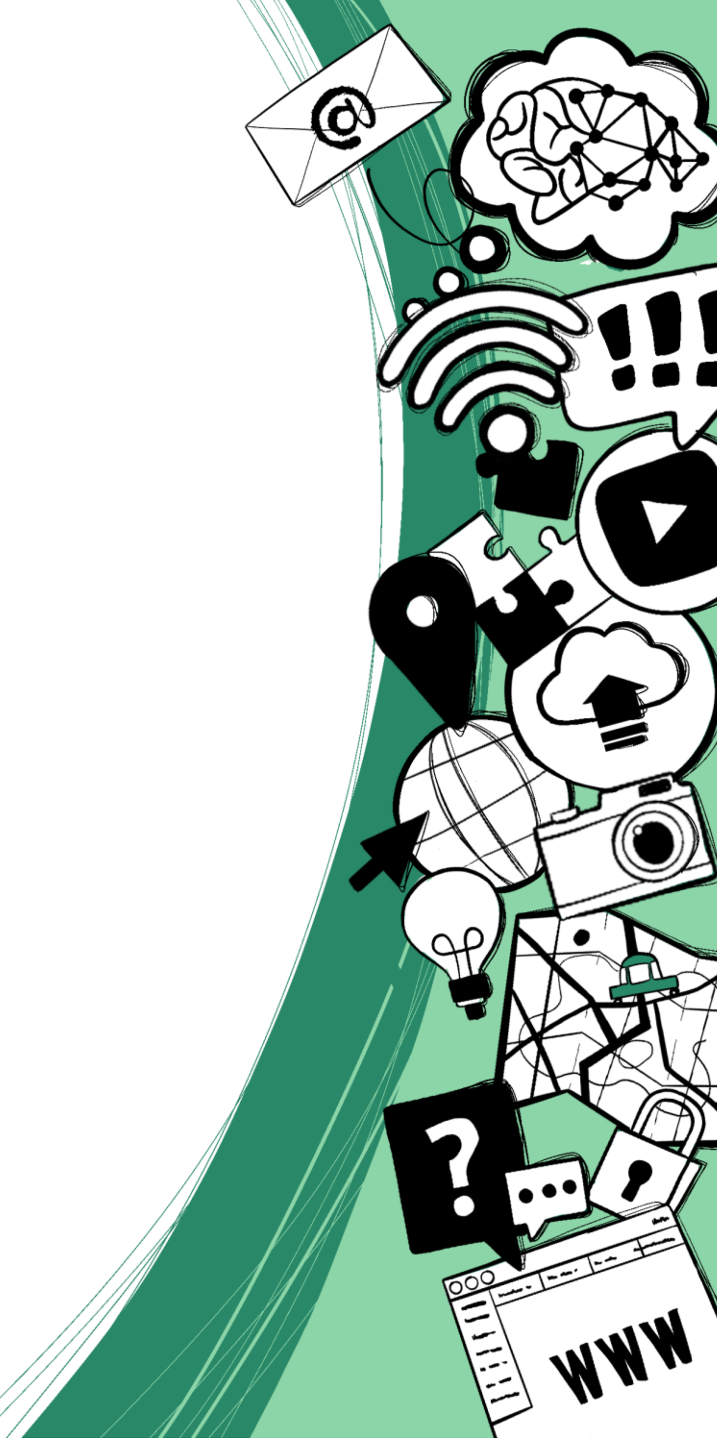


0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	44	42	44	0	0	0	0
0	0	37	0	0	0	0	0	43	0	0
0	0	7	0	0	0	0	0	2	0	0
0	6	0	0	0	0	0	0	0	19	0
0	2	0	0	0	0	0	0	0	3	0
0	0	47	0	0	0	0	0	41	0	0
0	0	0	52	0	0	0	49	0	0	0
0	0	0	0	27	0	37	0	0	0	0
0	0	0	0	27	0	37	0	0	0	0
0	0	0	0	27	0	37	0	0	0	0
0	0	0	0	27	0	37	0	0	0	0
0	0	0	0	27	0	37	0	0	0	0
0	0	0	0	27	0	36	0	0	0	0

Comparison with original image



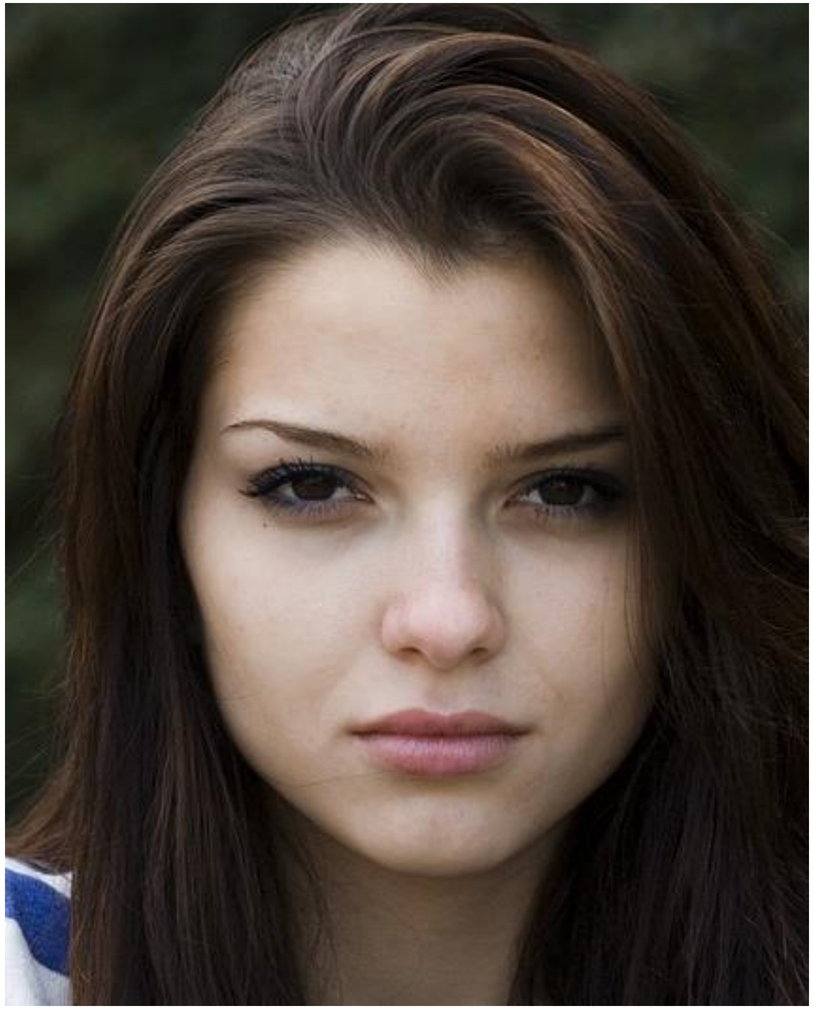
- Can the computer 'recognize' what's in the picture?
- No – further steps are necessary for this
- Further processing of the detected edges
  - **Recognizing shapes (rectangle, circle, ...)**
  - **Supervised Learning**



ENARIS

Face Recognition

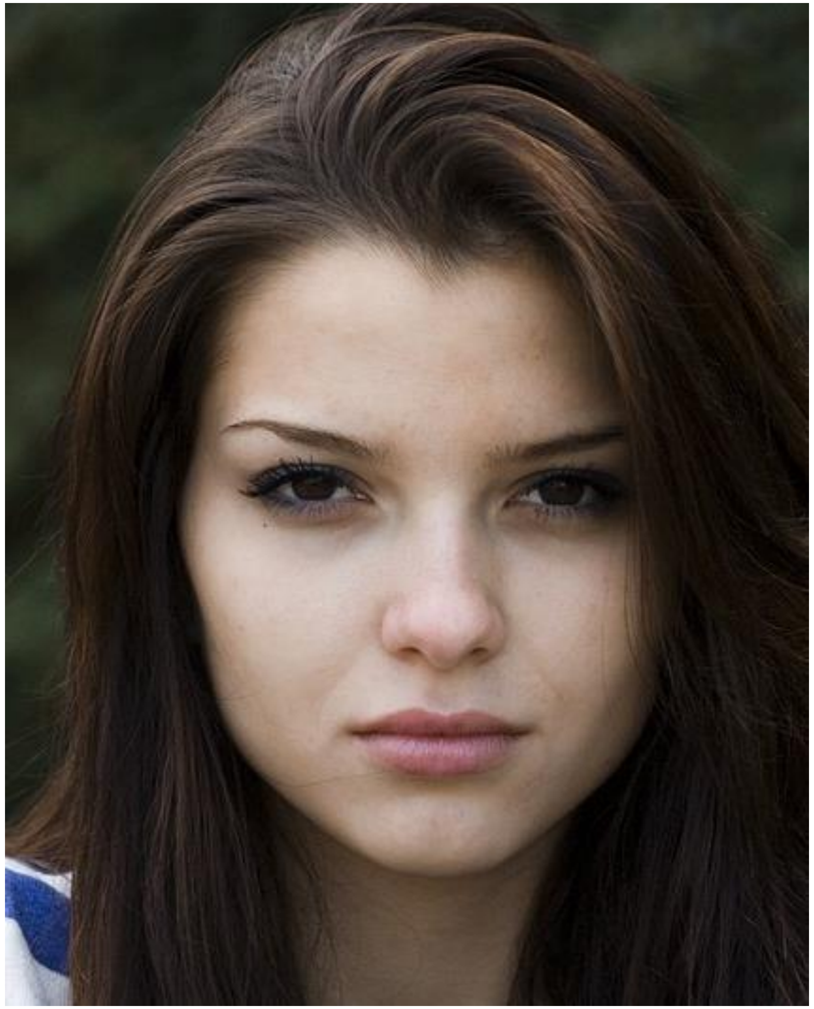
Face recognition



How would you recognize a face in a picture?

ENARIS

face recognition

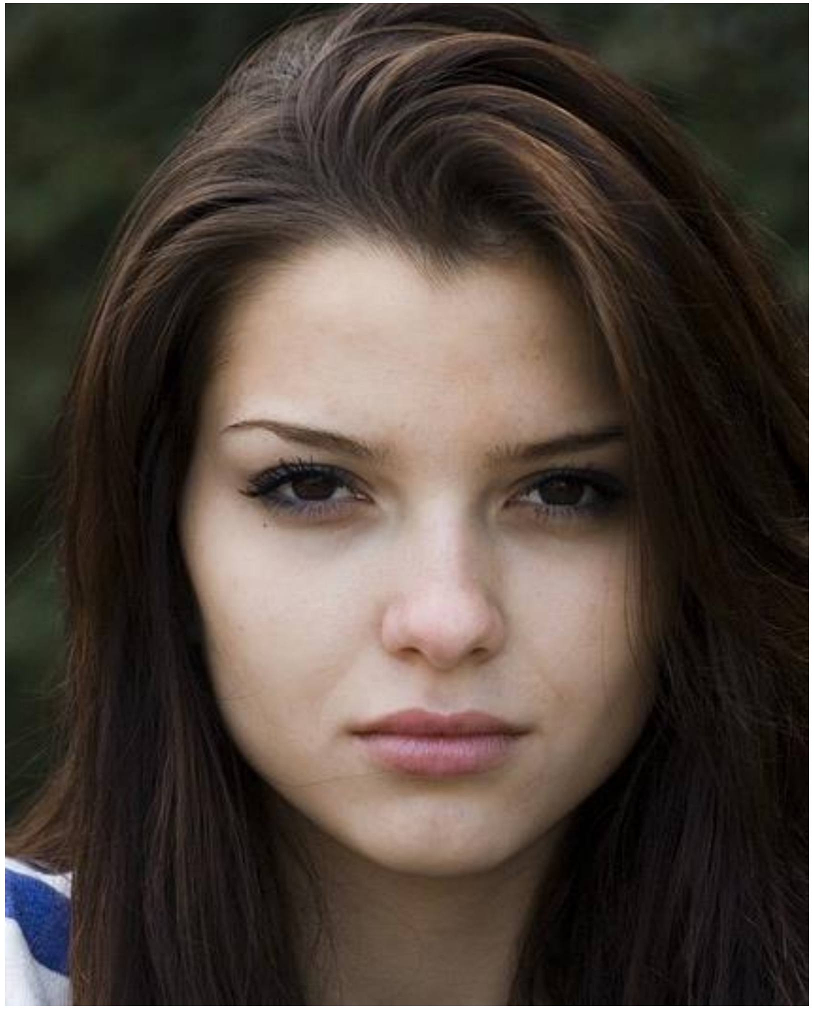


What *features* does a human face have?

- *Eyebrows are darker than the forehead*
- *Bridge of the nose is lighter than...*
- *Other features?*

ENARIS

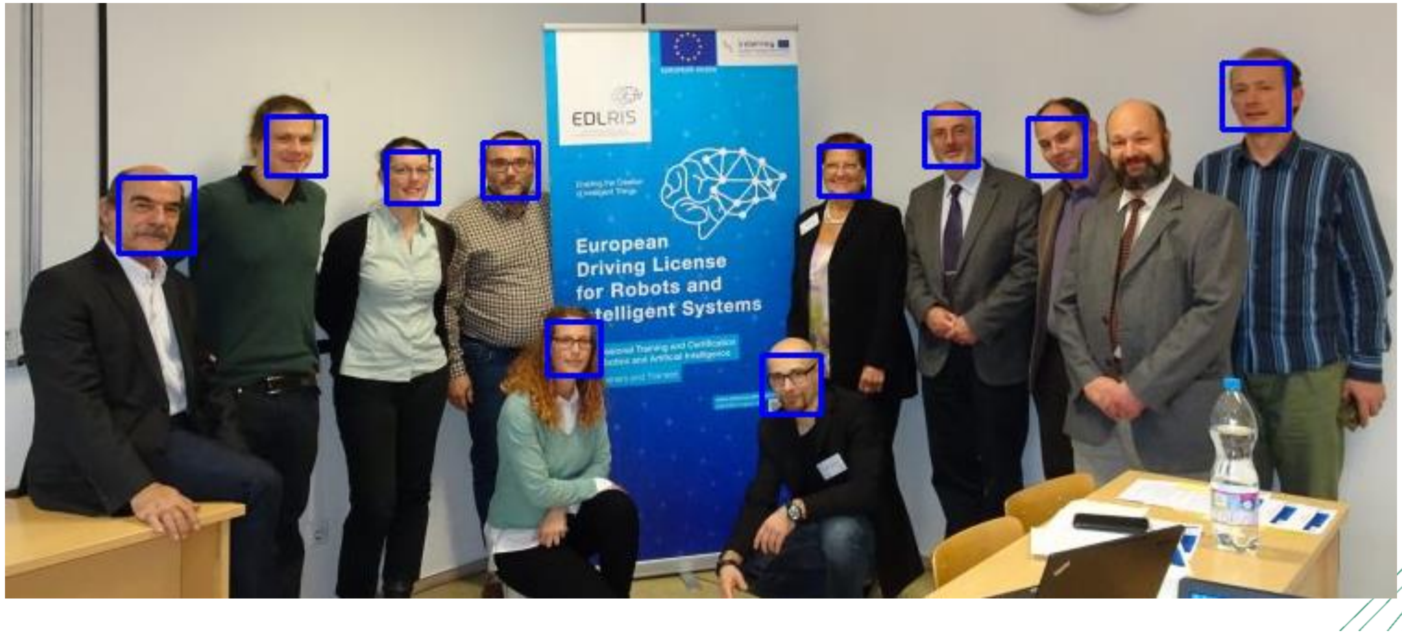
Face recognition



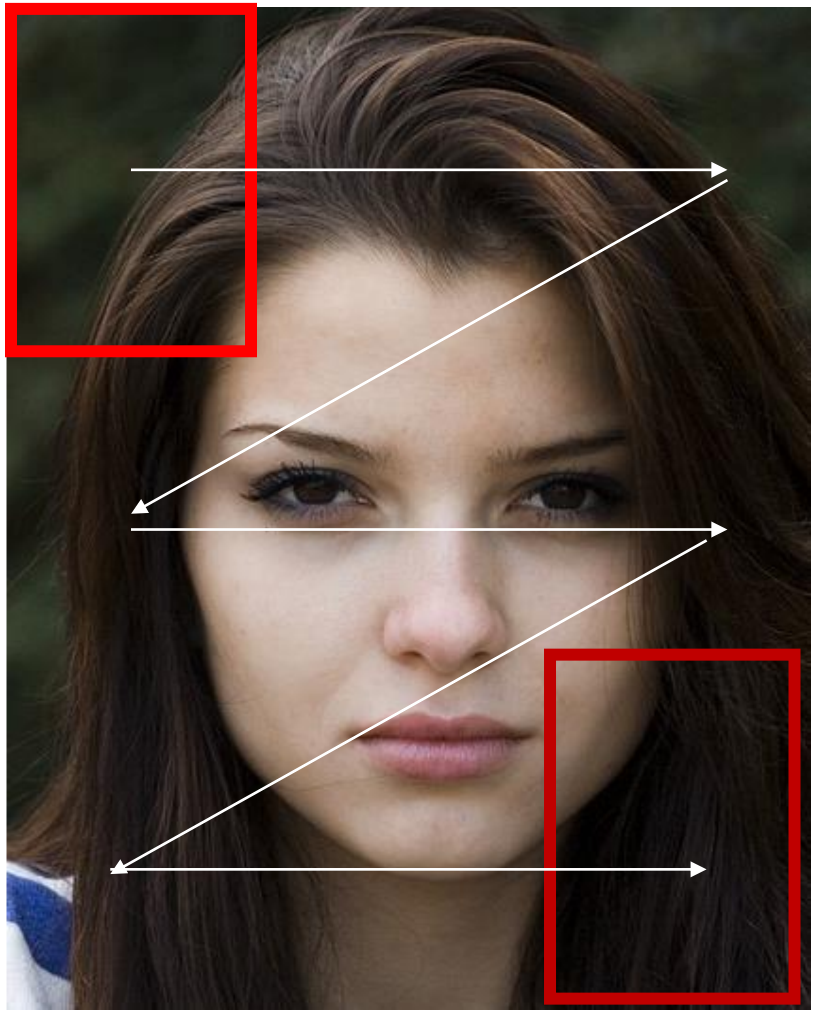
How does a computer recognize a face in an image?

Viola Jones Algorithm

- developed in 2001 by Paul Viola and Michael Jones
- efficient pattern recognition in real time
- pictures and videos
- detects faces , but does not distinguish them



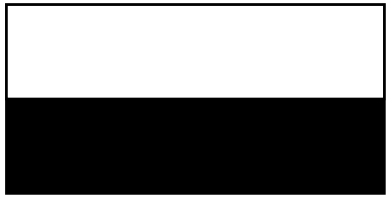
Sliding window



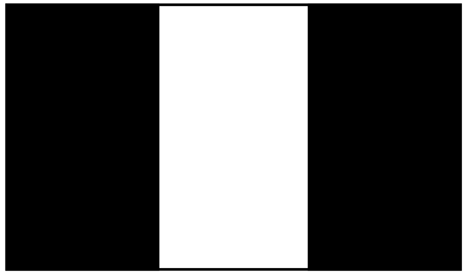
- Images can contain more than one face
- Sections (red rectangle) are examined
- The size of the subsections is adjusted

Essentials Viola Jones

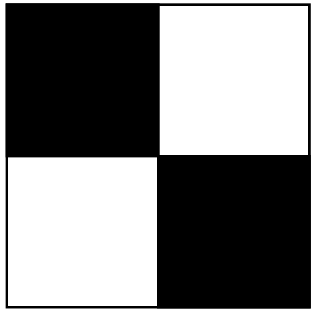
- **Haar-like features** are small boxes that use mathematical calculations to help the algorithm recognize the different parts of a face



edge features

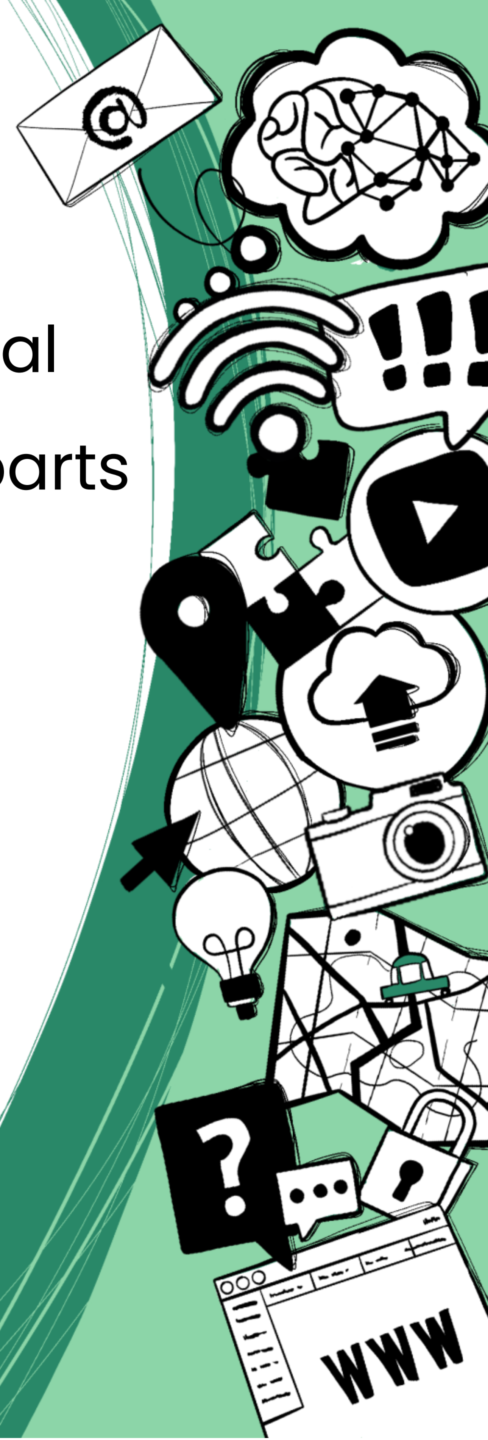


line features

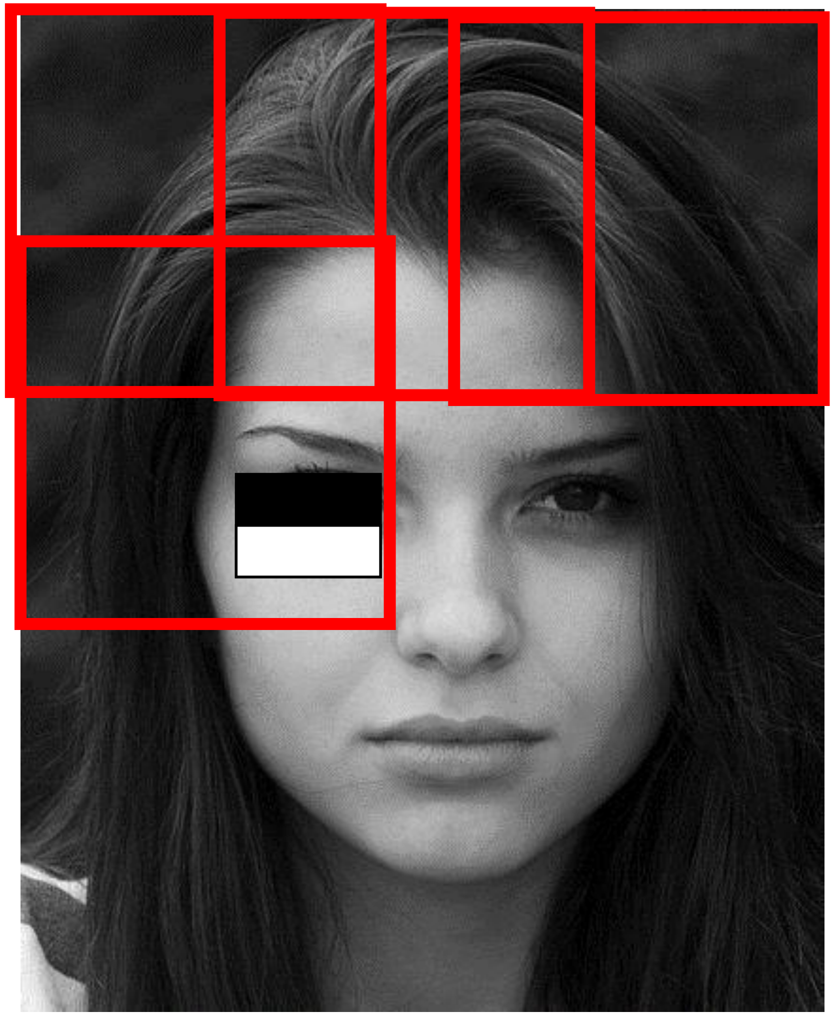


four rectangle features

- Features do not have a fixed size and can be adjusted as needed



Haar-like features



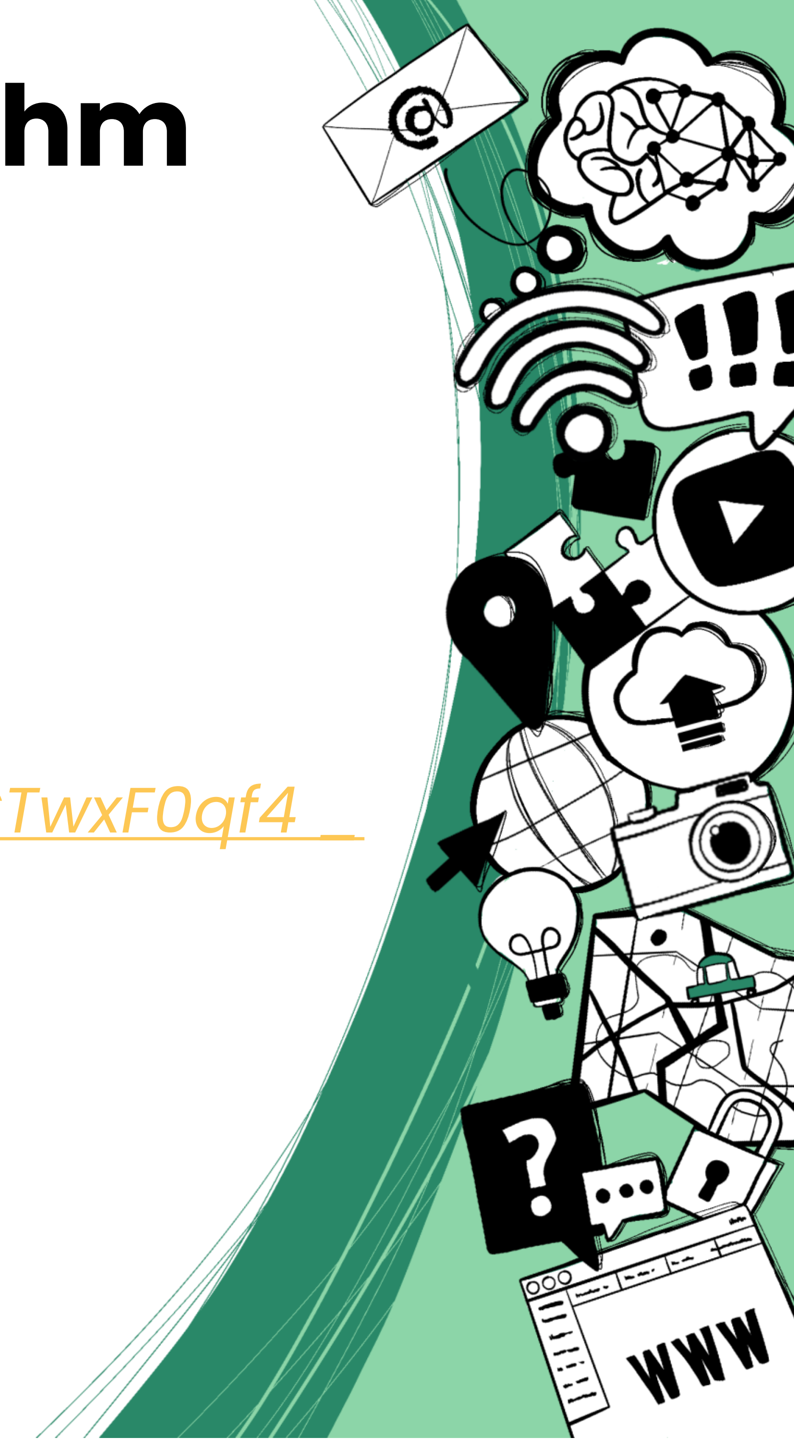
- Image converted to grayscale
- Search for specific characteristics (features)

So how does this algorithm work?

... let's look at a few practical *examples*

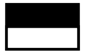
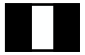
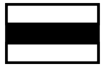
Link *to video :*

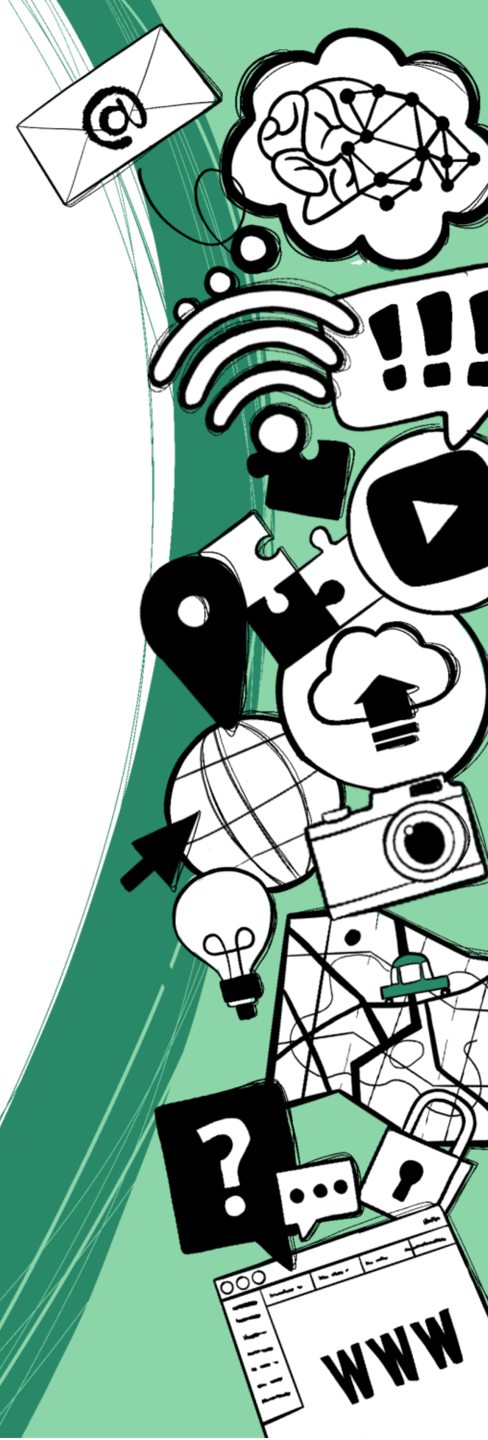
https://www.youtube.com/watch?v=hPCTwxF0qf4 _



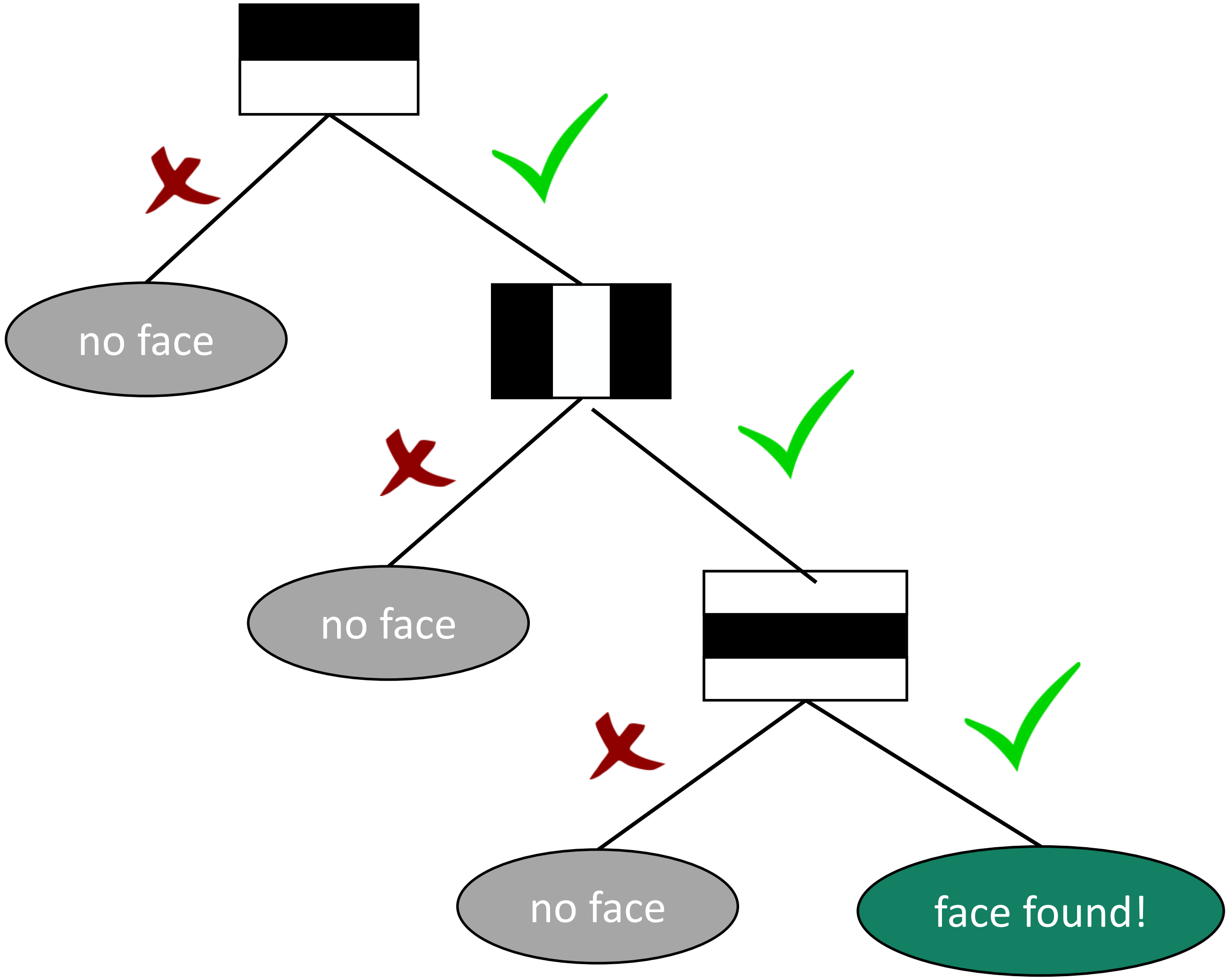
ENARIS

Worksheet Viola Jones

1. First, place the red rectangle with the top left corner on section **A1** of the printed image
2. Investigate which features would fit in the current segment (red rectangle). Proceed in the following order:
   a) check first 
   b) then 
   c) finally 
   d) if one of the features does not appear in the segment, you can go straight to step 3
   e) a face was only recognized if all three features occur in a segment
3. Place the red rectangle one after the other on segment B1, C1, A2, B2, C2, A3, B3, C3, A4, B4, C4 and repeat step 2 for each segment

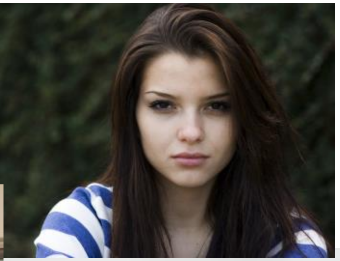


Worksheet Viola Jones



Exercise advanced

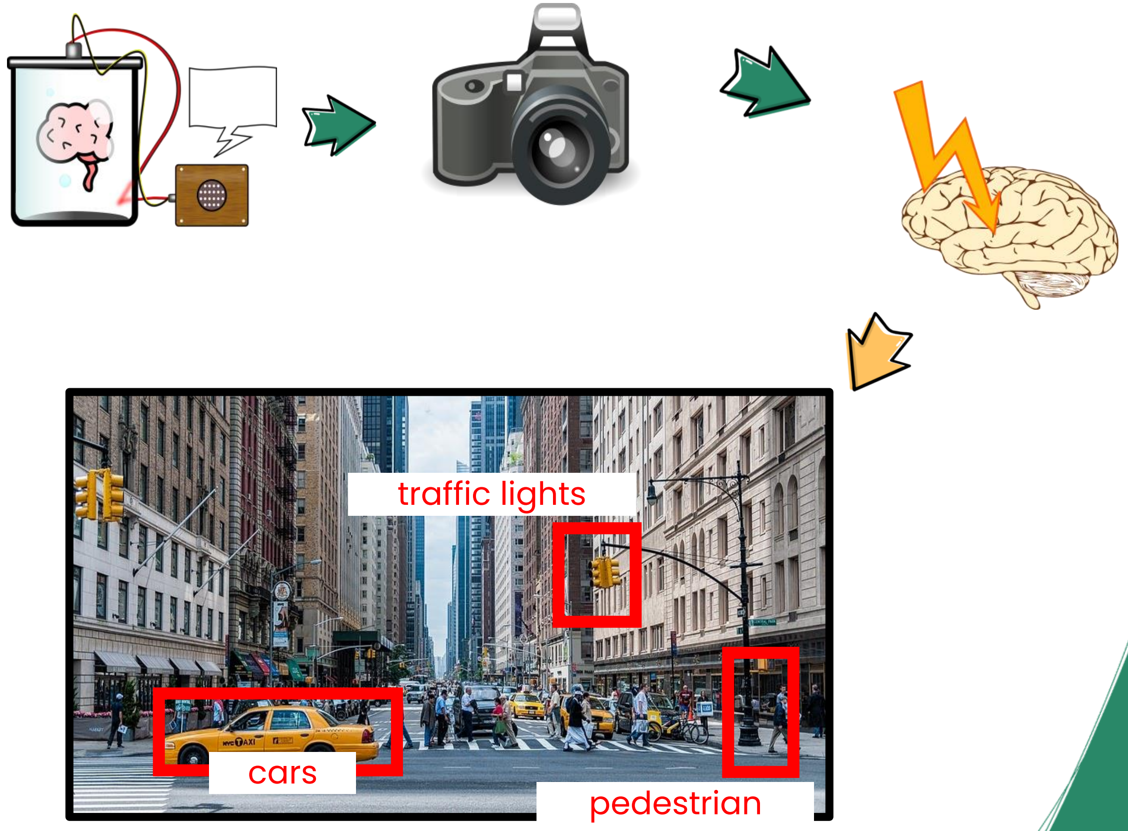
- Try the Viola Jones algorithm in Python (`ViolaJones.py`)
- Change the following parameters to recognize as many faces as possible in the images:
  - `scaleFactor`
  - `minNeighbors`
  - `minSize`



Machine Learning in CV

Short Summary

1. train model
2. Enter image with object(s) to be recognized
3. Process image and compare with trained model
4. output of the results



Supervised Learning

ENARIS

Now it's time to develop *your own computer vision algorithm* !

https://machinelearningforkids.co.uk/?lang=en

"Face Unlock for Smartphones"

Discussion

Opportunities and Limitations

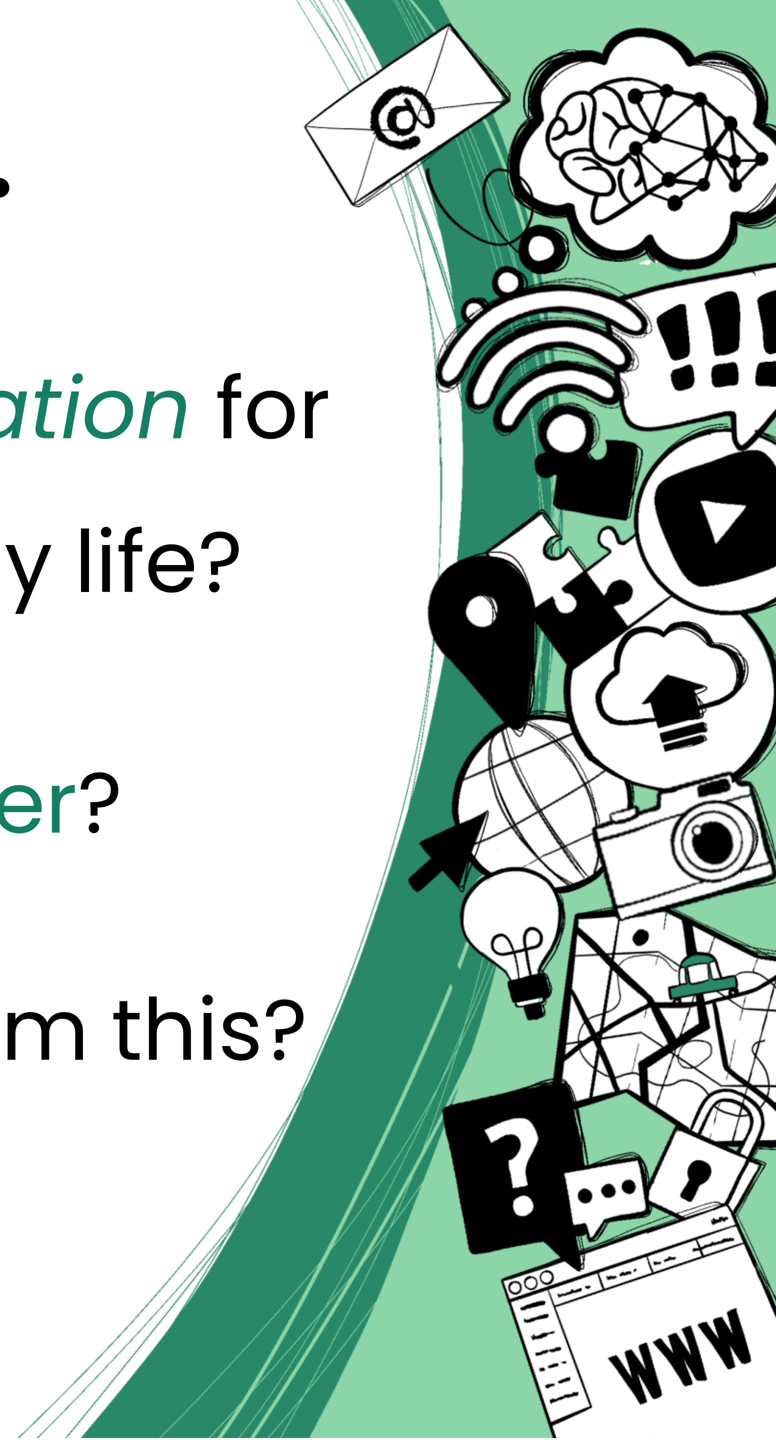
ENARIS

Time for the discussions...

Can you think of an *exciting application* for *computer vision* *from* your everyday life?

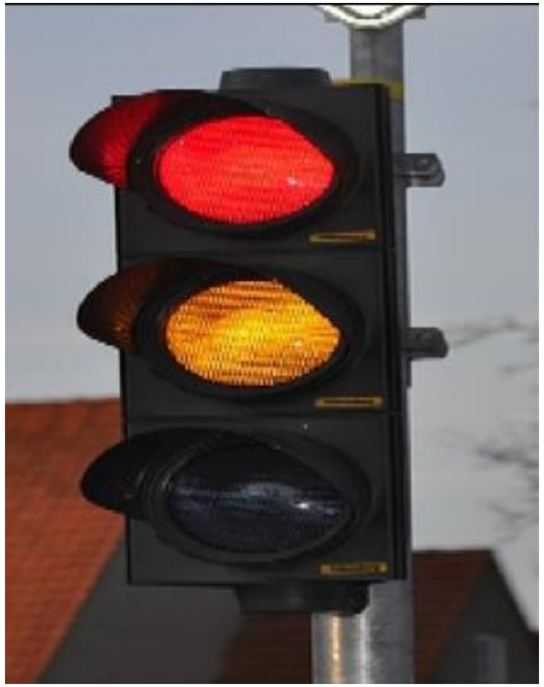
How could you confuse the computer?

… and what dangers could result from this?



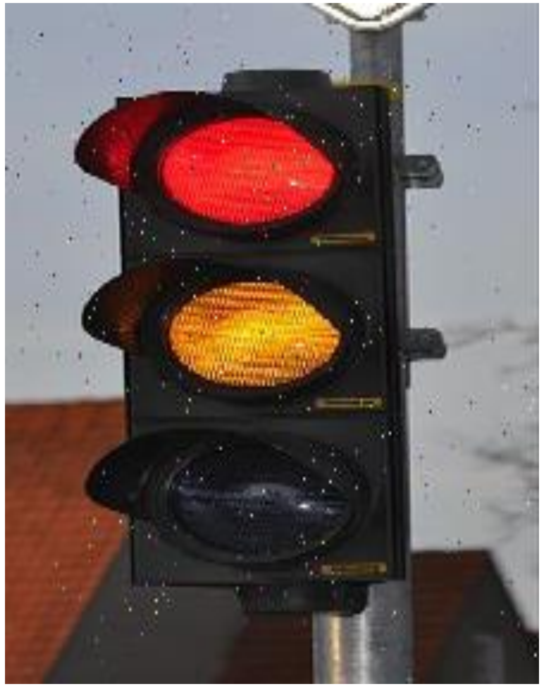
Fooling the AI

original image



classified as:
traffic light (99%)

after pixel changes



classified as:
Can Opener (85%)