

Plan of Attack

What we will learn in this section:

- Viola-Jones algorithm
- Haar-Like features
- Integral image
- Training classifiers
- Adaptive Boosting (Adaboost)
- Cascading

The Viola-Jones Algorithm

The Viola-Jones Algorithm



Paul Viola



Michael Jones

The Viola-Jones Algorithm

2001

The Viola-Jones Algorithm

The Viola-Jones Algorithm



Training



Detection

The Viola-Jones Algorithm



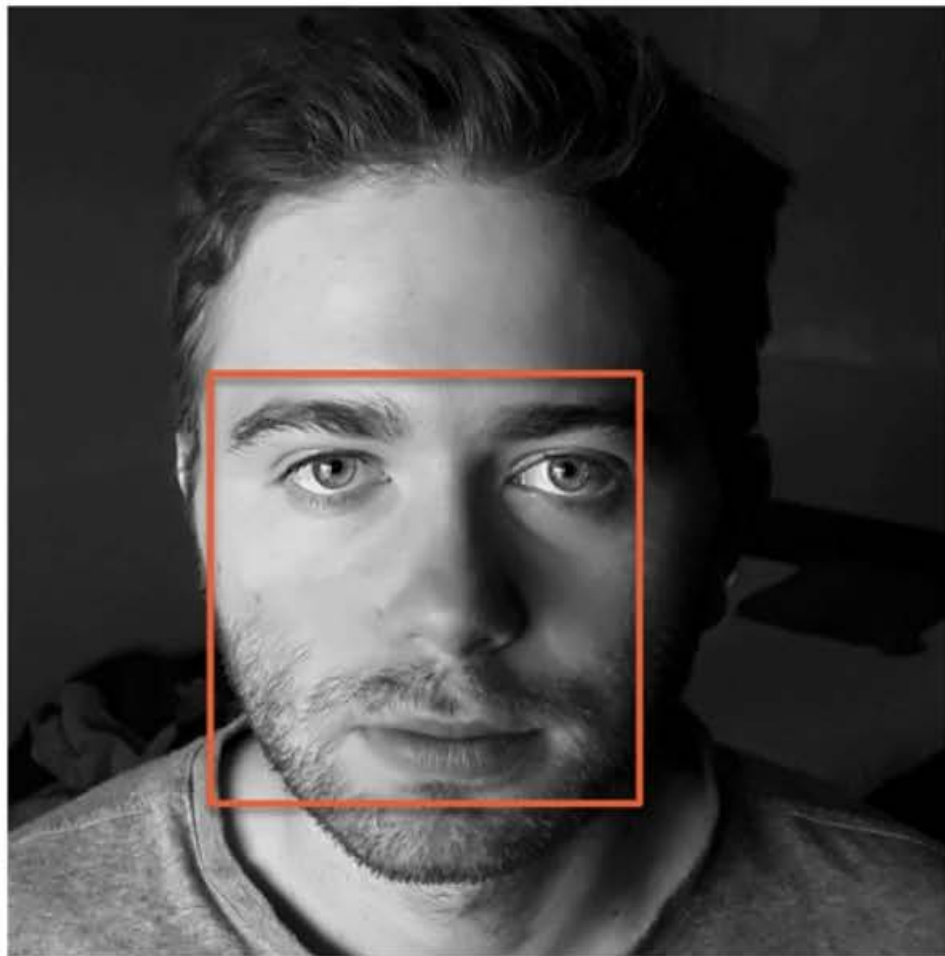
"JD"

The Viola-Jones Algorithm



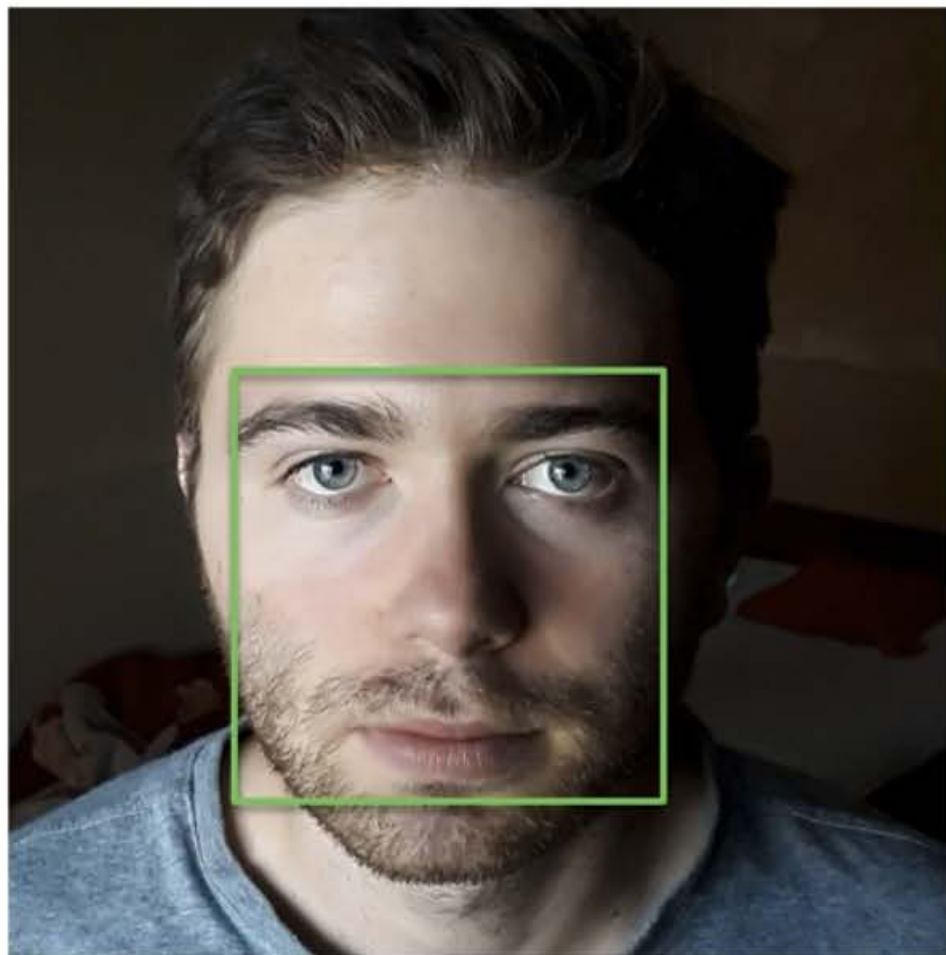
"JD"

The Viola-Jones Algorithm



"JD"

The Viola-Jones Algorithm



"JD"

Haar-like Features

Haar-like Features

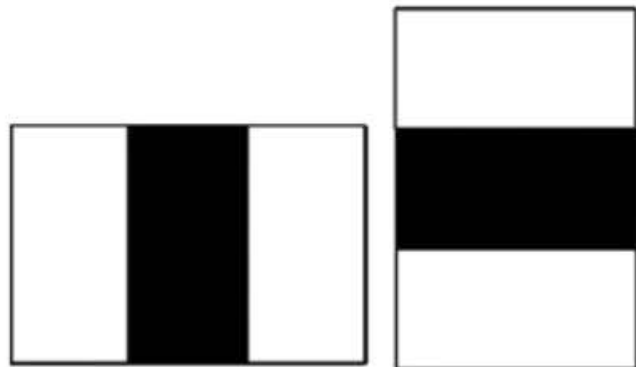


Alfred Haar

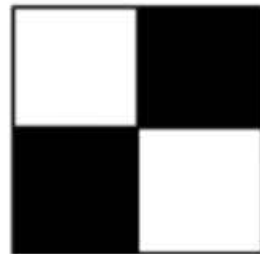
Haar-like Features



Edge Features

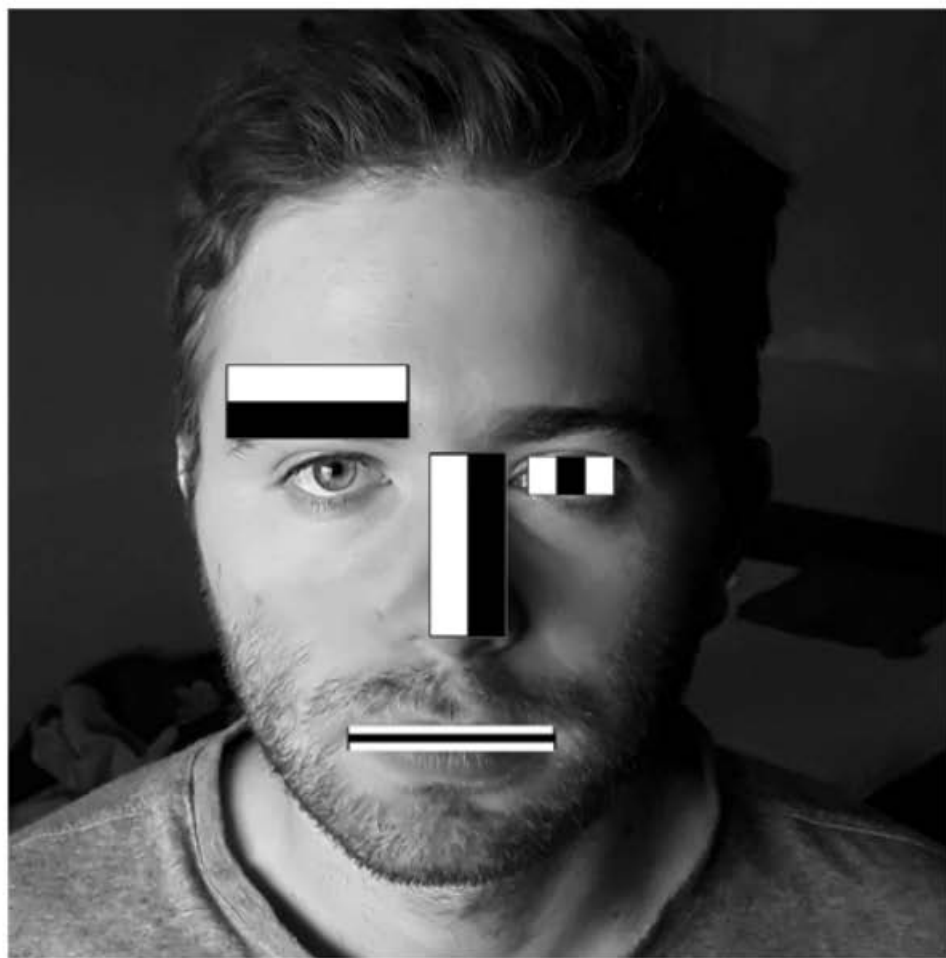


Line Features



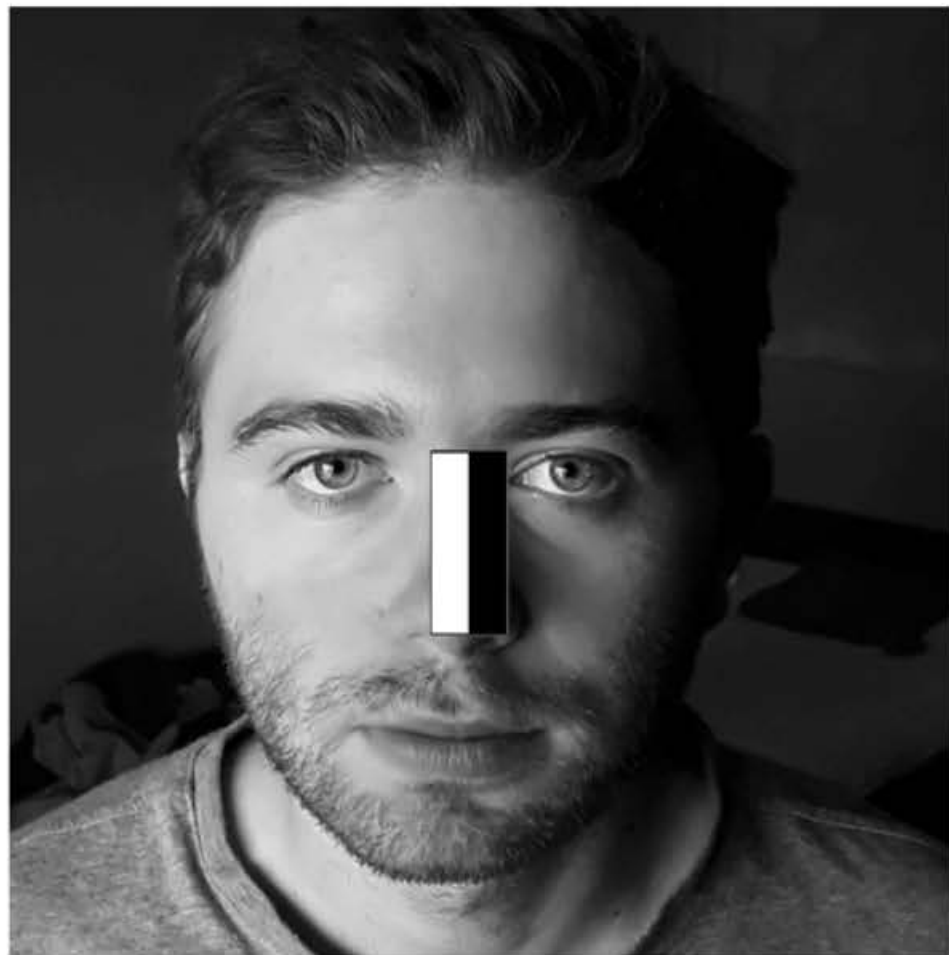
Four-rectangle Features

Haar-like Features

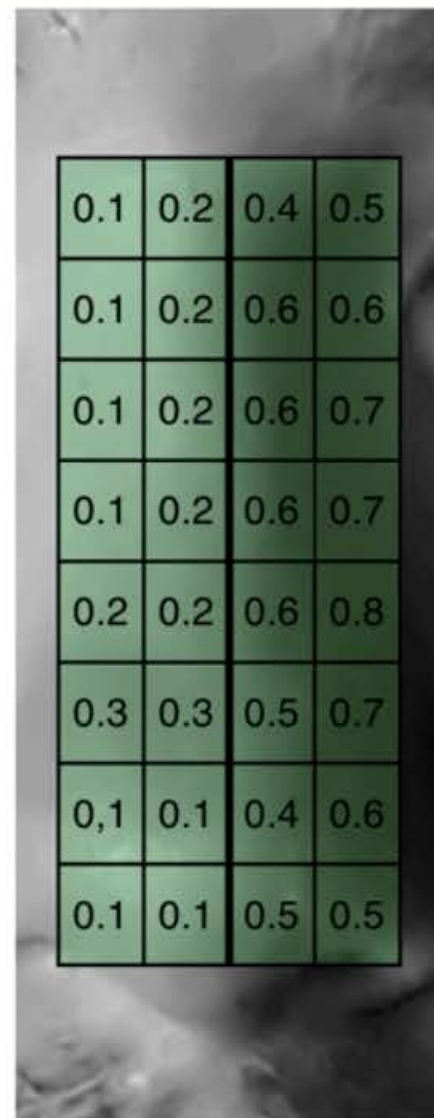


"JD"

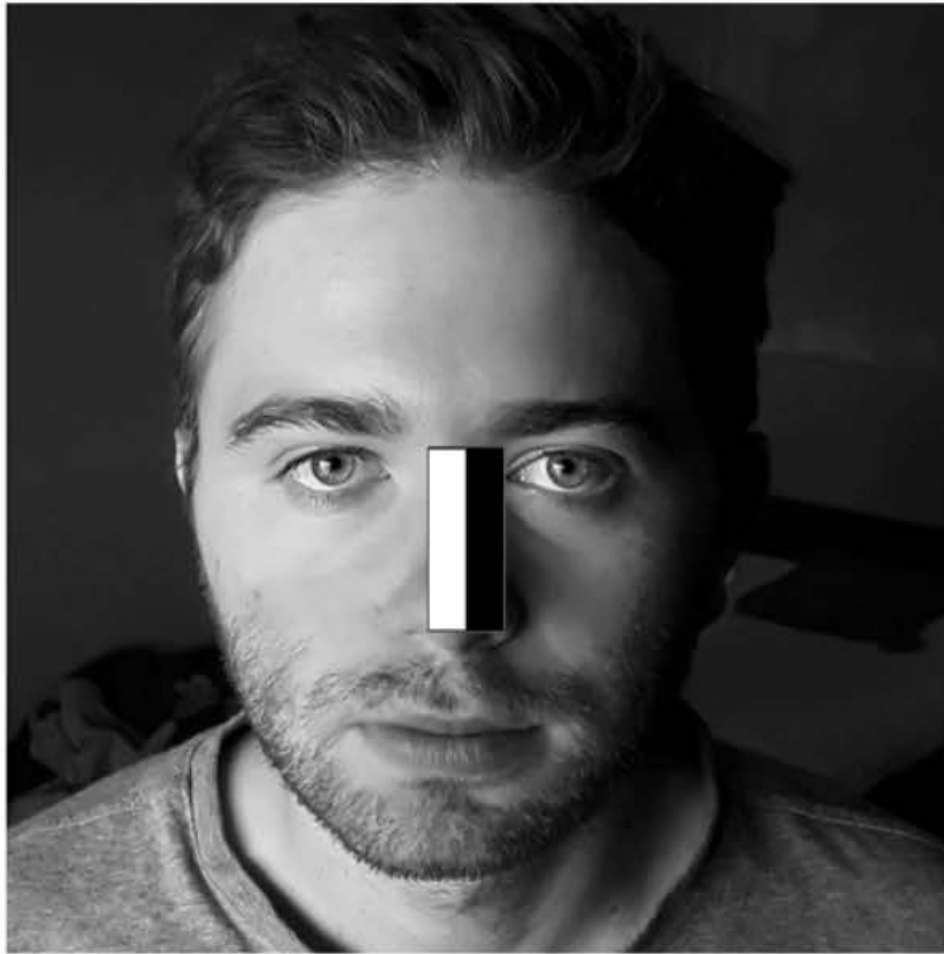
Haar-like Features



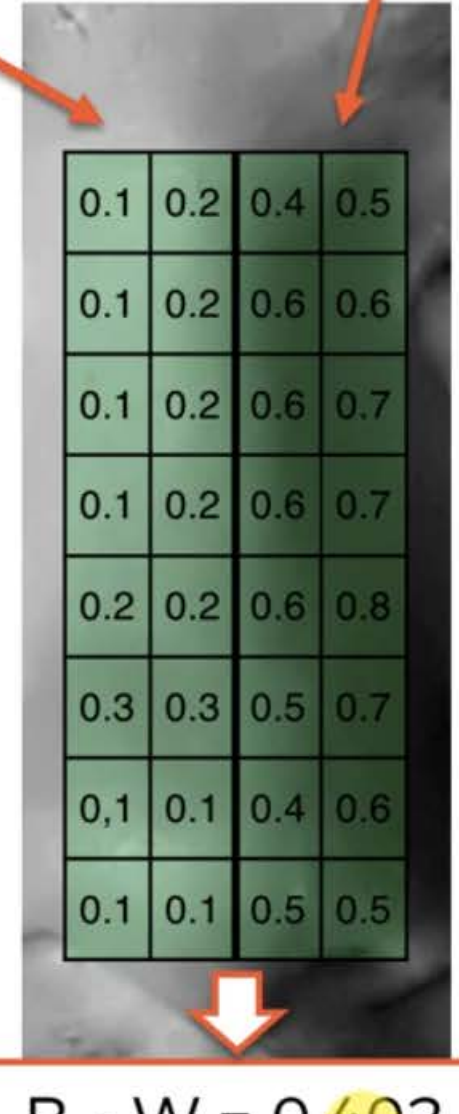
"JD"



Haar-like Features



"JD"



0.166

0.568

B - W = 0.402

Integral Image

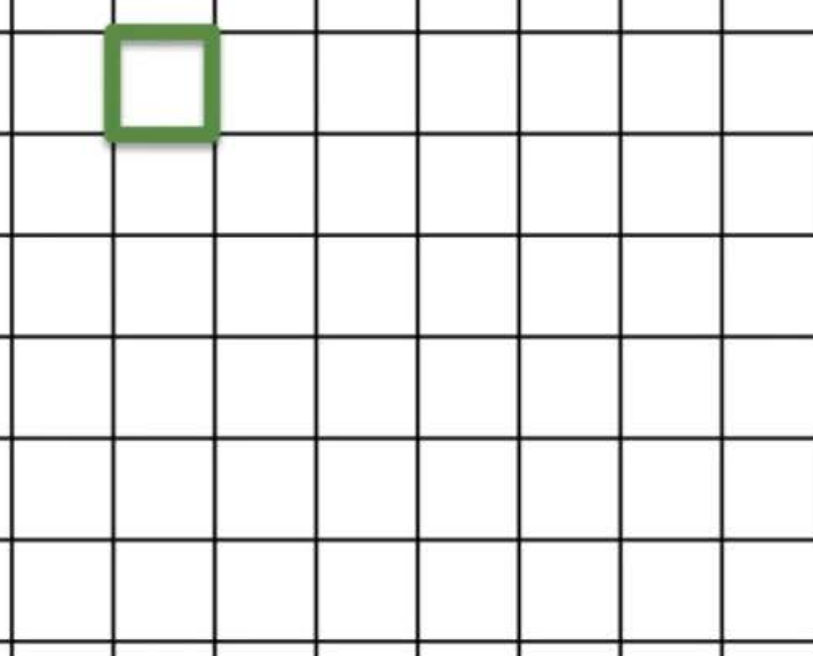
1	2	5	7	2	8	0	6	4	6
9	8	0	4	9	5	10	7	10	3
7	6	10	2	0	10	4	9	10	8
3	8	1	5	4	8	0	9	5	8
9	5	0	1	3	4	1	9	6	1
1	2	5	6	9	9	0	2	4	0
1	2	4	1	6	6	10	4	2	5
5	6	2	10	5	3	9	10	10	2

Integral Image

Image

1	2	5	7	2	8	0	6	4	6
9	8	0	4	9	5	10	7	10	3
7	6	10	2	0	10	4	9	10	8
3	8	1	5	4	8	0	9	5	8
9	5	0	1	3	4	1	9	6	1
1	2	5	6	9	9	0	2	4	0
1	2	4	1	6	6	10	4	2	5
5	6	2	10	5	3	9	10	10	2

Integral image

A 10x10 grid with a green square in the second row, third column. The grid is composed of 10 columns and 10 rows. The green square is located in the second row from the top and the third column from the left. It is a solid green square with a slightly darker green border.

Integral Image

Image

1	2	5	7	2	8	0	6	4	6
9	8	0	4	9	5	10	7	10	3
7	6	10	2	0	10	4	9	10	8
3	8	1	5	4	8	0	9	5	8
9	5	0	1	3	4	1	9	6	1
1	2	5	6	9	9	0	2	4	0
1	2	4	1	6	6	10	4	2	5
5	6	2	10	5	3	9	10	10	2

Integral image

[illegible]

Integral Image

Image

1	2	5	7	2	8	0	6	4	6
9	8	0	4	9	5	10	7	10	3
7	6	10	2	0	10	4	9	10	8
3	8	1	5	4	8	0	9	5	8
9	5	0	1	3	4	1	9	6	1
1	2	5	6	9	9	0	2	4	0
1	2	4	1	6	6	10	4	2	5
5	6	2	10	5	3	9	10	10	2

Integral image

A 10x10 grid with a green square at (4, 4) and the number 25 at (2, 8).

Integral Image

Image

1	2	5	7	2	8	0	6	4	6
9	8	0	4	9	5	10	7	10	3
7	6	10	2	0	10	4	9	10	8
3	8	1	5	4	8	0	9	5	8
9	5	0	1	3	4	1	9	6	1
1	2	5	6	9	9	0	2	4	0
1	2	4	1	6	6	10	4	2	5
5	6	2	10	5	3	9	10	10	2

Integral image

1	3	8	15	17	25	25	31	35	41
10	20	25	36	47	60	70	83	97	106
17	33	48	61	72	95	109	131	155	172
20	44	60	78	93	124	138	169	198	223
29	58	74	93	111	146	161	201	236	262
30	61	82	107	134	178	193	235	274	300
31	64	89	115	148	198	223	269	310	341
36	75	102	138	176	229	263	319	370	403

Integral Image

Image

1	2	5	7	2	8	0	6	4	6
9	8	0	4	9	5	10	7	10	3
7	6	10	2	0	10	4	9	10	8
3	8	1	5	4	8	0	9	5	8
9	5	0	1	3	4	1	9	6	1
1	2	5	6	9	9	0	2	4	0
1	2	4	1	6	6	10	4	2	5
5	6	2	10	5	3	9	10	10	2

Integral image

1	3	8	15	17	25	25	31	35	41
10	20	25	36	47	60	70	83	97	106
17	33	48	61	72	95	109	131	155	172
20	44	60	78	93	124	138	169	198	223
29	58	74	93	111	146	161	201	236	262
30	61	82	107	134	178	193	235	274	300
31	64	89	115	148	198	223	269	310	341
36	75	102	138	176	229	263	319	370	403

Integral Image

Image

1	2	5	7	2	8	0	6	4	6
9	8	0	4	9	5	10	7	10	3
7	6	10	2	0	10	4	9	10	8
3	8	1	5	4	8	0	9	5	8
9	5	0	1	3	4	1	9	6	1
1	2	5	6	9	9	0	2	4	0
1	2	4	1	6	6	10	4	2	5
5	6	2	10	5	3	9	10	10	2

Integral image

1	3	8	15	17	25	25	31	35	41
10	20	25	36	47	60	70	83	97	106
17	33	48	61	72	95	109	131	155	172
20	44	60	78	93	124	138	169	198	223
29	58	74	93	111	146	161	201	236	262
30	61	82	107	134	178	193	235	274	300
31	64	89	115	148	198	223	269	310	341
36	75	102	138	176	229	263	319	370	403

235

Integral Image

Image

1	2	5	7	2	8	0	6	4	6
9	8	0	4	9	5	10	7	10	3
7	6	10	2	0	10	4	9	10	8
3	8	1	5	4	8	0	9	5	8
9	5	0	1	3	4	1	9	6	1
1	2	5	6	9	9	0	2	4	0
1	2	4	1	6	6	10	4	2	5
5	6	2	10	5	3	9	10	10	2

Integral image

1	3	8	15	17	25	25	31	35	41
10	20	25	36	47	60	70	83	97	106
17	33	48	61	72	95	109	131	155	172
20	44	60	78	93	124	138	169	198	223
29	58	74	93	111	146	161	201	236	262
30	61	82	107	134	178	193	235	274	300
31	64	89	115	148	198	223	269	310	341
36	75	102	138	176	229	263	319	370	403

235

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83

Integral Image

Image

1	2	5	7	2	8	0	6	4	6
9	8	0	4	9	5	10	7	10	3
7	6	10	2	0	10	4	9	10	8
3	8	1	5	4	8	0	9	5	8
9	5	0	1	3	4	1	9	6	1
1	2	5	6	9	9	0	2	4	0
1	2	4	1	6	6	10	4	2	5
5	6	2	10	5	3	9	10	10	2

Integral image

1	3	8	15	17	25	25	31	35	41
10	20	25	36	47	60	70	83	97	106
17	33	48	61	72	95	109	131	155	172
20	44	60	78	93	124	138	169	198	223
29	58	74	93	111	146	161	201	236	262
30	61	82	107	134	178	193	235	274	300
31	64	89	115	148	198	223	269	310	341
36	75	102	138	176	229	263	319	370	403

$$235 - 83 + 47$$

Integral Image

Image

1	2	5	7	2	8	0	6	4	6
9	8	0	4	9	5	10	7	10	3
7	6	10	2	0	10	4	9	10	8
3	8	1	5	4	8	0	9	5	8
9	5	0	1	3	4	1	9	6	1
1	2	5	6	9	9	0	2	4	0
1	2	4	1	6	6	10	4	2	5
5	6	2	10	5	3	9	10	10	2

Integral image

1	3	8	15	17	25	25	31	35	41
10	20	25	36	47	60	70	83	97	106
17	33	48	61	72	95	109	131	155	172
20	44	60	78	93	124	138	169	198	223
29	58	74	93	111	146	161	201	236	262
30	61	82	107	134	178	193	235	274	300
31	64	89	115	148	198	223	269	310	341
36	75	102	138	176	229	263	319	370	403

$$235 - 83 + 47 - 134 = 65$$

Training Classifiers

The Viola-Jones Algorithm



Training

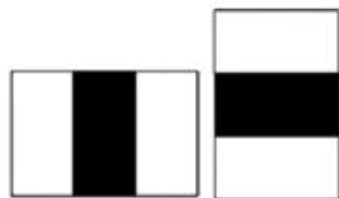


Detection

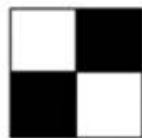
Training Classifiers



Edge Features



Line Features



Four-Rectangle
Features

Training Classifiers



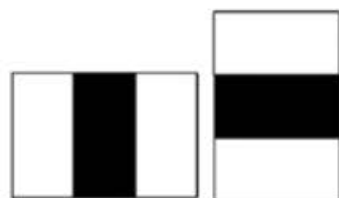
24px



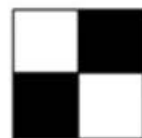
24px



Edge Features



Line Features



Four-Rectangle
Features

Training Classifiers



Face Images



Non-Face Images

Adaboost

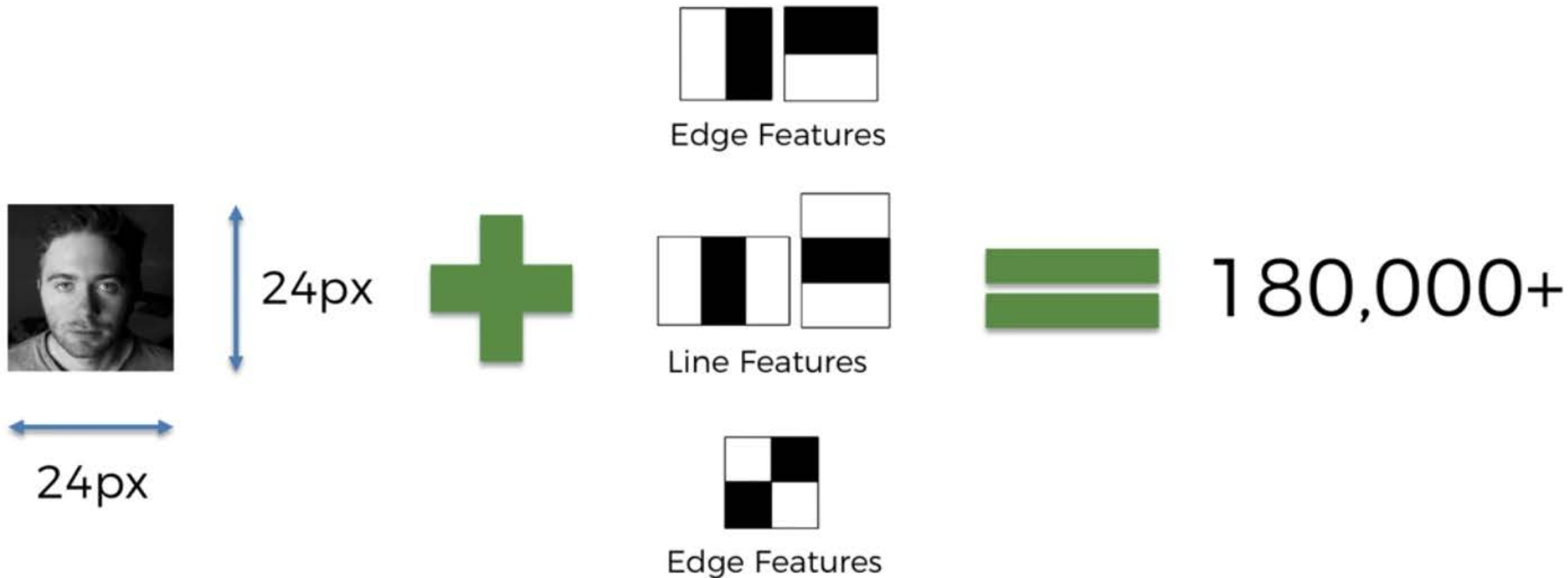


Face Images



Non-Face Images

Adaboost



Adaboost



$$F(x) = \alpha_1 f_1(x) + \alpha_2 f_2(x) + \alpha_3 f_3(x) + \dots$$

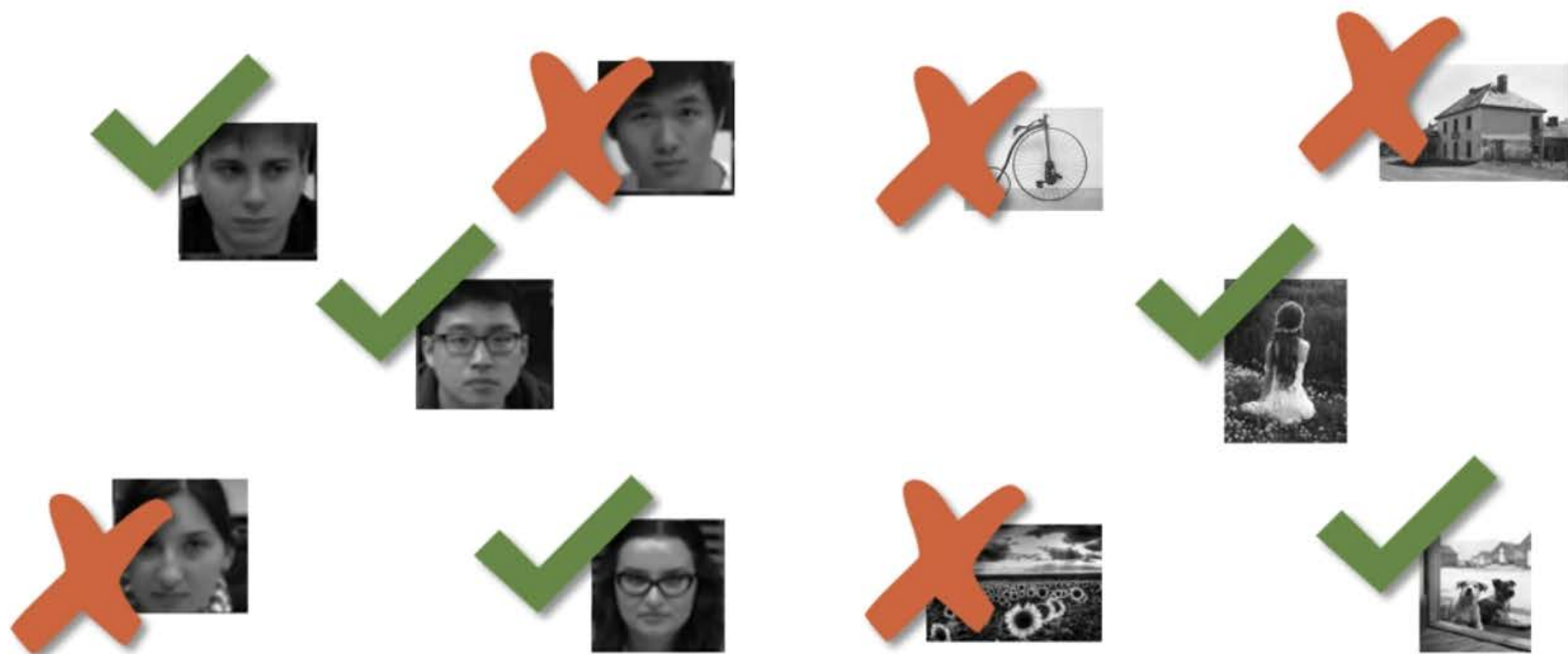


Strong Classifier

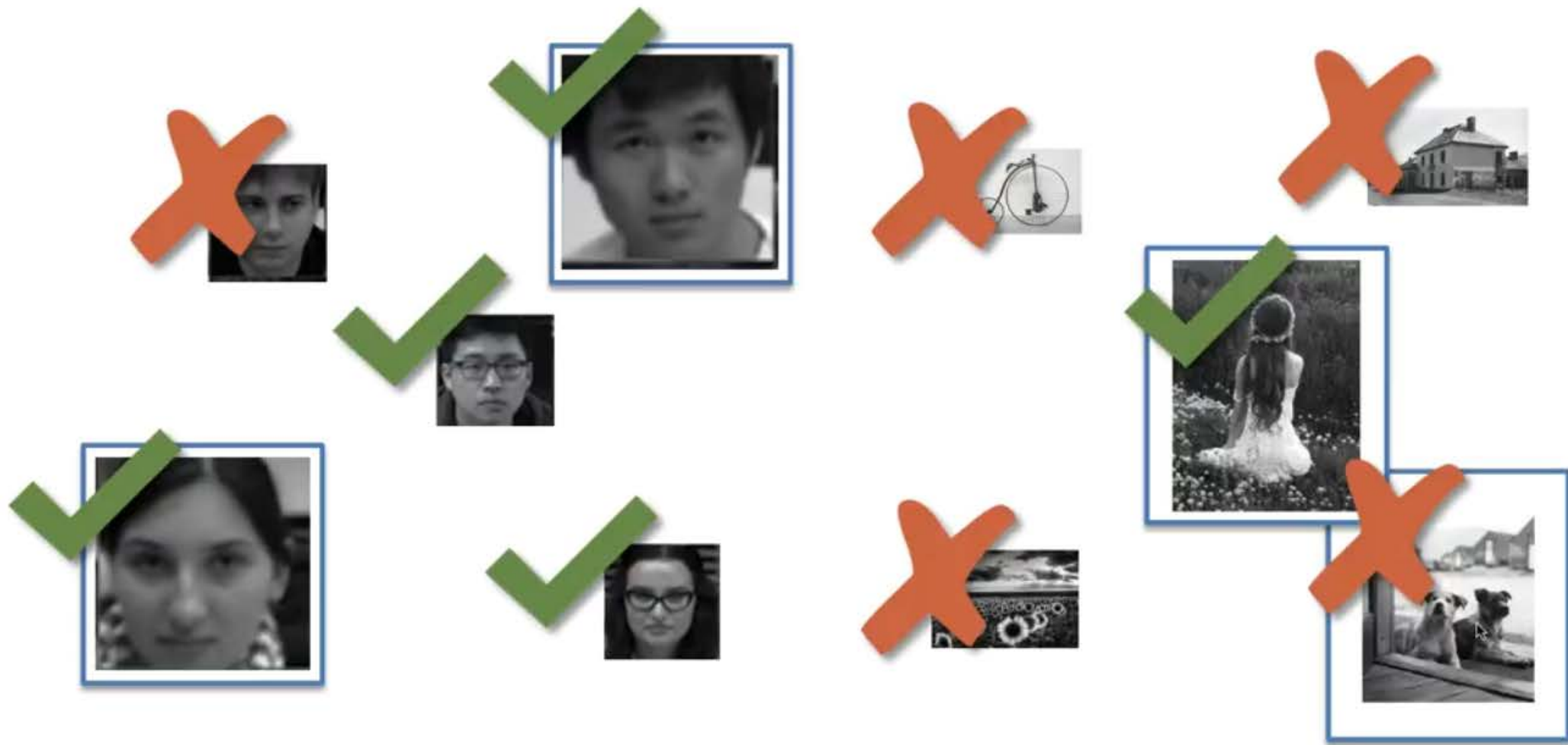


Weak Classifier

Adaboost



Adaboost



Adaboost



$$F(x) = \alpha_1 f_1(x) + \alpha_2 f_2(x) + \alpha_2 f_2(x) + \dots$$

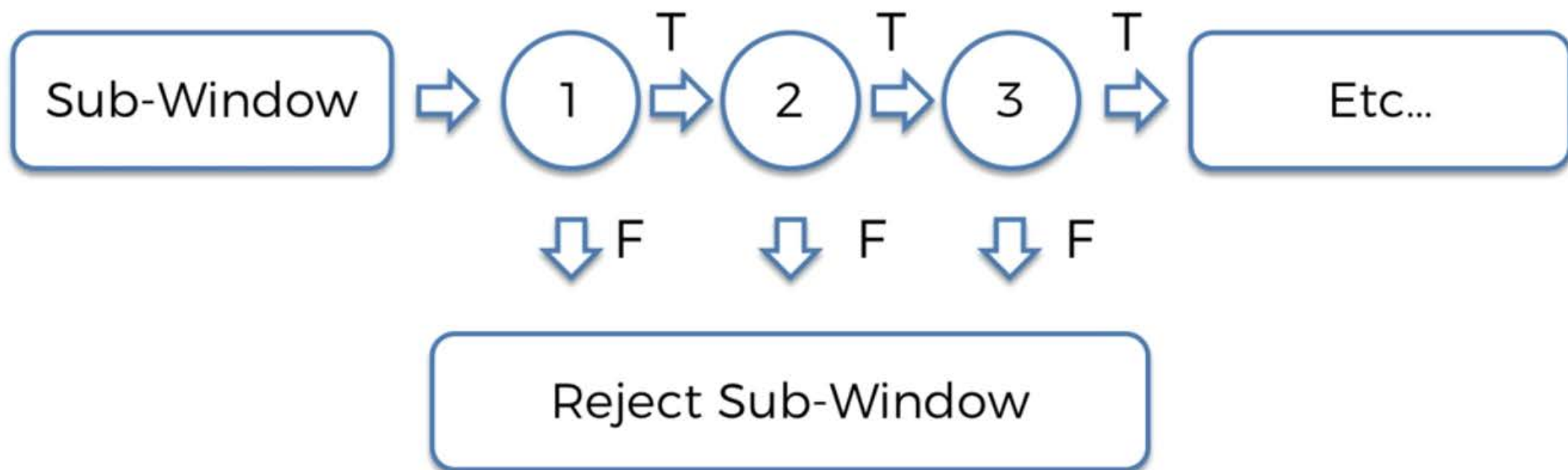


Stephen

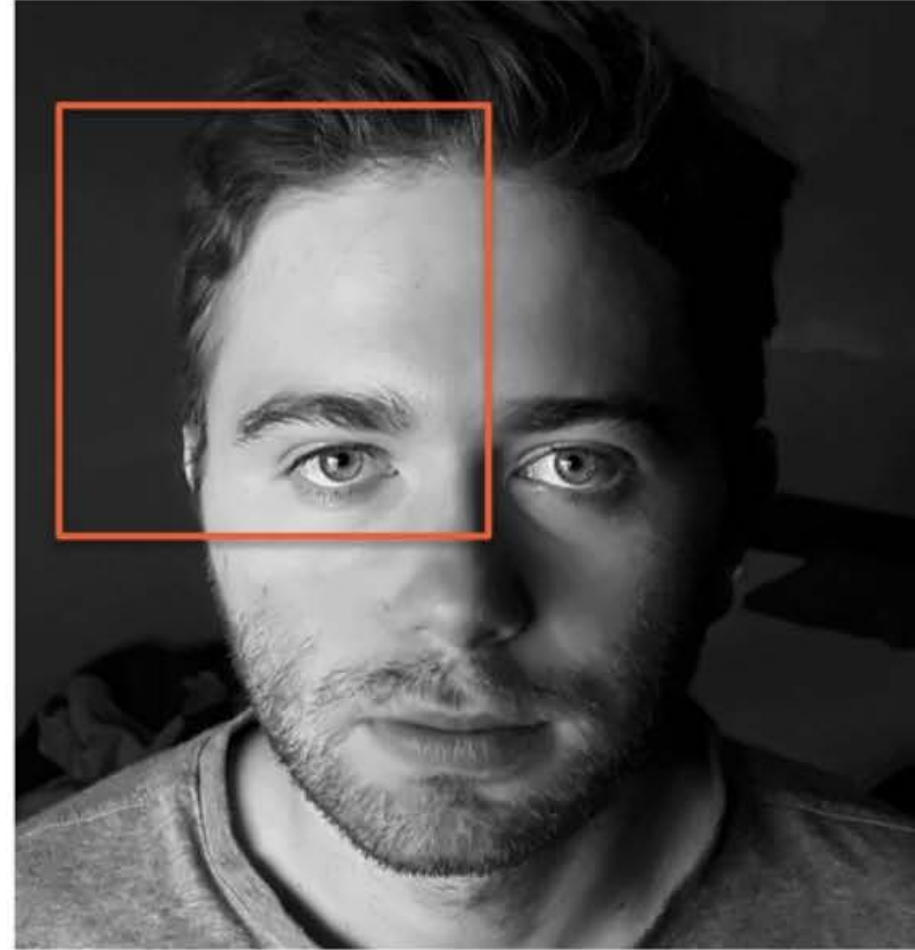
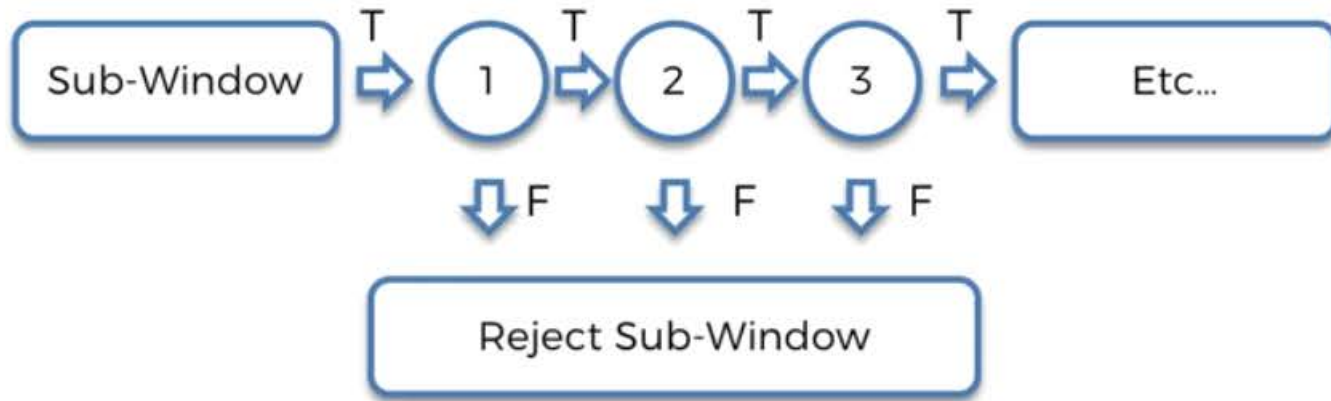
Cascading



$$F(x) = \alpha_1 f_1(x) + \alpha_2 f_2(x) + \alpha_3 f_3(x) + \dots$$



Cascading



“JD”