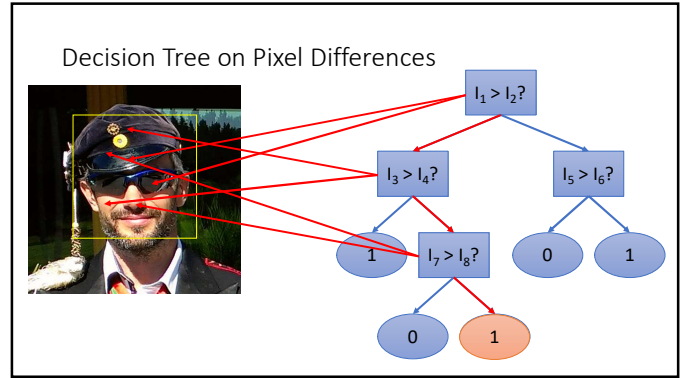
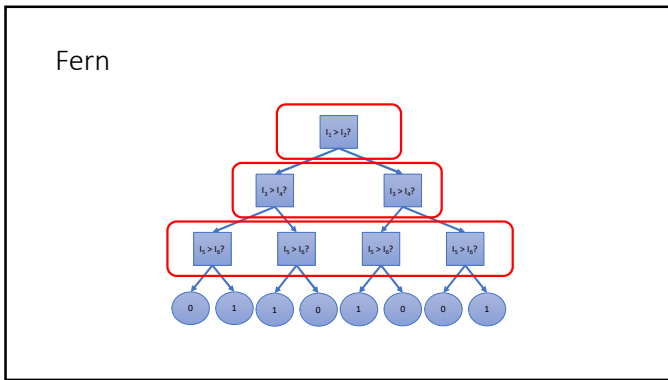


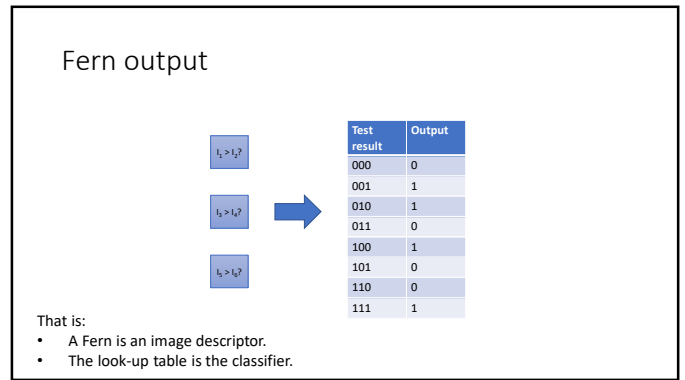
7



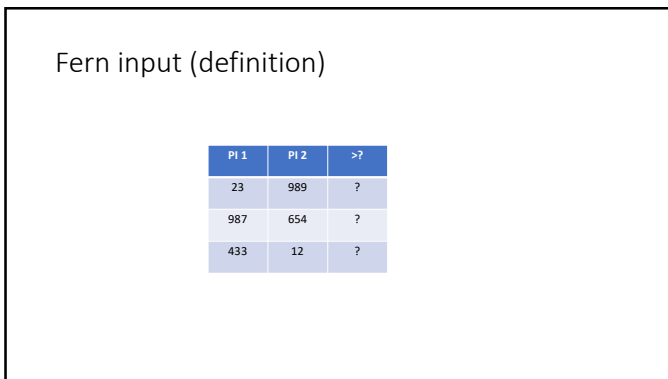
8



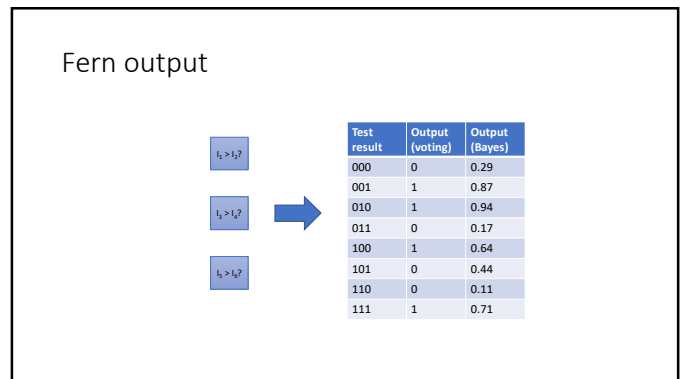
9



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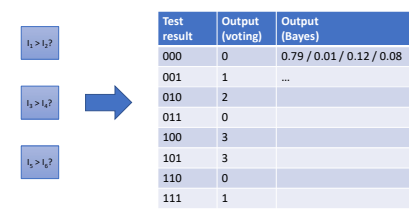


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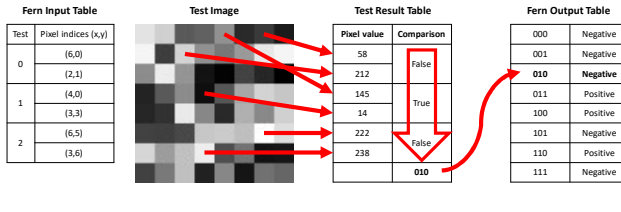
### Fern output - multiclass



Test result	Output (voting)	Output (Bayes)
000	0	0.79 / 0.01 / 0.12 / 0.08
001	1	...
010	2	
011	0	
100	3	
101	3	
110	0	
111	1	

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### A Fern with depth = 3



Test	Pixel indices (k,y)
0	(6,0)
	(2,1)
1	(4,0)
	(3,3)
2	(6,5)
	(3,6)

Pixel value	Comparison
58	False
212	True
145	True
14	True
222	False
238	010

Test result	Output
000	Negative
001	Negative
010	Negative
011	Positive
100	Positive
101	Negative
110	Positive
111	Negative

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### Side note: Similar descriptors

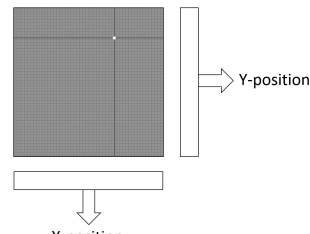
- Select the pixels to compare from a Gaussian distribution instead of uniform: BRIEF
- Oriented FAST and rotated BRIEF: ORB.
- Daisy-pattern sampling: BRISK.

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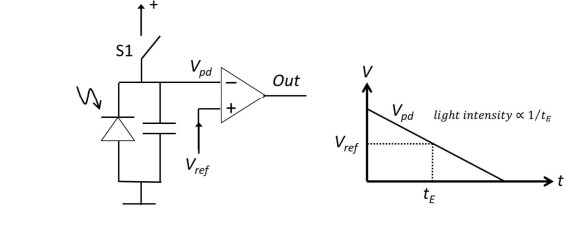
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### Address-Event Representation (AER)



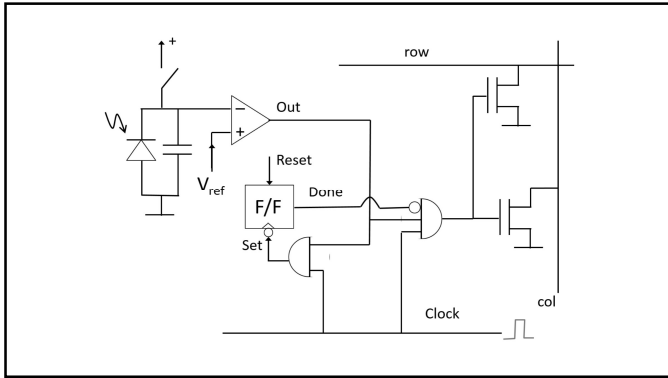
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### Intensity-Ranking Image Sensor (IRIS)



The graph shows a sawtooth-like voltage response over time. The peak voltage is  $V_{pd}$  and the reference voltage is  $V_{ref}$ . The time constant is  $t_E$ . The relationship is given as  $light\ intensity \propto 1/t_E$ .

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Result:  
A sequence of pixel addresses in intensity-ranked order.

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BACK TO FERNS

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Ferns\*

PI 1	PI 2	>?	Done
23	989	?	0
987	654	?	0
433	12	?	0

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Ferns\*\*

PI	Comp	Fern	Test
12	0	17	2
23	1	17	0
433	1	17	2
654	0	17	1
987	1	17	1
989	0	17	0

Fern #17	
Comp	Done
?	0
?	0
?	0

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Toy example

PI	Comp	Fern	Test
0	0	0	0
1	0	1	0
2	1	1	0
3	0	2	0
4	1	0	0
5	1	2	0

Input image: 1 2 5 4 3 0

Fern #0		Output	
Comp	Done		
?	0	0	0
		1	1

Fern #1		Output	
Comp	Done		
?	0	0	0
		1	1

Fern #2		Output	
Comp	Done		
?	0	0	1
		1	0

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### Toy example

PI	Comp	Fern	Test
0	0	0	0
1	0	1	0
2	1	1	0
3	0	2	0
4	1	0	0
5	1	2	0

Input image: 1 2 5 4 3 0

Fern #0

Comp	Done	Output
?	0	1 1

Fern #1

Comp	Done	Output
0	1	1 1

Fern #2

Comp	Done	Output
?	0	0 1
1	0	1 1

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### Toy example

PI	Comp	Fern	Test
0	0	0	0
1	0	1	0
2	1	1	0
3	0	2	0
4	1	0	0
5	1	2	0

Input image: 1 2 5 4 3 0

Fern #0

Comp	Done	Output
?	0	0 0
1	1	1 1

Fern #1

Comp	Done	Output
0	1	0 0
1	1	1 1

Fern #2

Comp	Done	Output
?	0	0 1
1	0	1 0

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### Toy example

PI	Comp	Fern	Test
0	0	0	0
1	0	1	0
2	1	1	0
3	0	2	0
4	1	0	0
5	1	2	0

Input image: 1 2 5 4 3 0

Fern #0

Comp	Done	Output
?	0	0 0
1	1	1 1

Fern #1

Comp	Done	Output
0	1	0 0
1	1	1 1

Fern #2

Comp	Done	Output
1	1	0 1
1	0	1 0

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### Ferns\*\*\*: Groves

Look-up instead of search!

PI	Comp	Fern	Level
...	...	...	...
12	0	17	2
...	...	...	...
23	1	17	0
...	...	...	...
433	1	17	2
...	...	...	...
654	0	17	1
...	...	...	...
987	1	17	1
...	...	...	...
989	0	17	0
...	...	...	...

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### Forests → Ferns → Groves

- Restriction 1: All levels have the same tests (Forests → Ferns)
- Restriction 2: Each pixel is used only once (Ferns → Groves)

Thus, in combination with an IRIS:











- The image is classified while read.
- The classification is finished before the entire image is read from the sensor.

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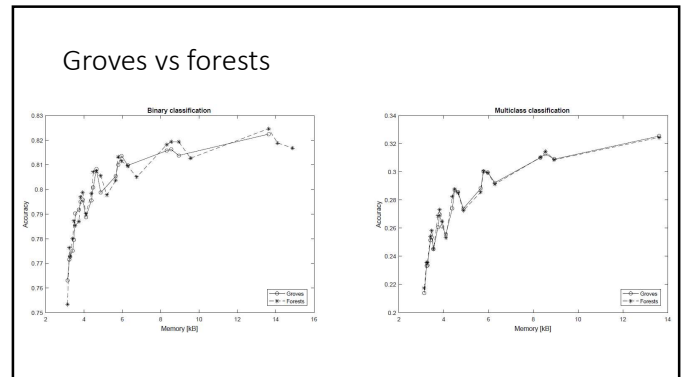
### Test on CIFAR-10

airplane	
automobile	
bird	
cat	
deer	
dog	
frog	
horse	
ship	
truck	

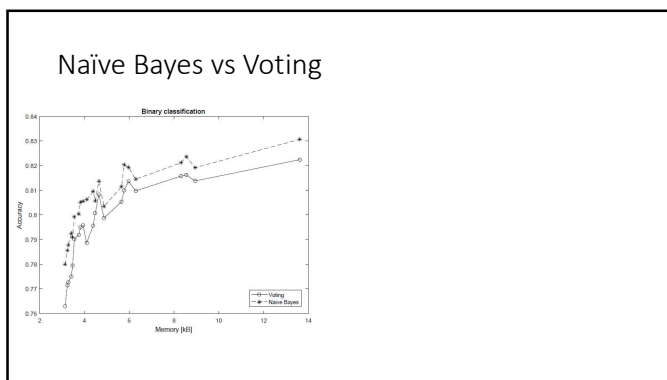
Test 1:  
Forest vs Grove

Test 2:  
Voting vs Naïve Bayes

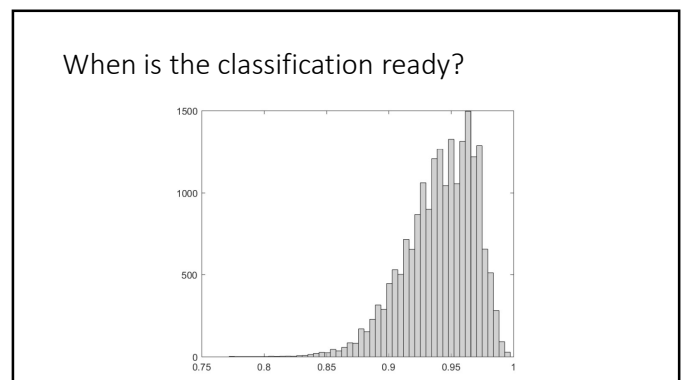
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### Conclusion

- Groves: Modified Ferns to work on intensity-sorted pixel indices.
- IRIS: An image sensor that outputs intensity-sorted pixel indices.
- IRIS + Groves:
  - Classification performance nowhere near state-of-the-art.
  - Image classification during image readout, ie, extremely fast.
  - Image classification very simple and power efficient.

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