Introduction to CNN

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Introduction to CNN Agenda

Introduction to CNN Agenda

How do we recognize digit? How does the CNN? **Convolutions for feature extraction Convolutional Neural Network (CNN)** Terminology **CNN** explainer









By summarized patterns from experience

























































By summarized patterns from experience Patterns: the features shared by all samples of one digit

"0" — a "circle"









By summarized patterns from experience Patterns: the features shared by all samples of one digit

"0" — a "circle""1" — a "close-to-vertical line"









By summarized patterns from experience Patterns: the features shared by all samples of one digit

"0" - a "circle"
"1" - a "close-to-vertical line"
"9" - a "circle" + a "close-to-vertical line"









By summarized patterns from experience

- "0" a "circle"
- "1" a "close-to-vertical line"
- "9" a "circle" + a "close-to-vertical line"
- "5" two reversed "corners"









By summarized patterns from experience

- "0" a "circle"
- "1" a "close-to-vertical line"
- "9" a "circle" + a "close-to-vertical line"
- "5" two reversed "corners"
- "3" the "connection between up and bottom"





By summarized patterns from experience

"0"	— a	"circle"		
"] "	— a	"close-t	o-vertical l	line"
"9"	— a	"circle"	+ a "close-	e-to-vertical line"
"5"	— t\	vo rever	sed "corne	ers"
"3"	— tł	ne "conn	ection betw	tween up and bottom"

By summarized patterns from experience

"0"	 а	"circle"				
"1"	 а	"close-t	0-Ve	ertical	line"	
"9"	 а	"circle"	+ a	"close	e-to-v	vertical line"
"5"	 tw	vo rever	sed	"corn	ers"	
"3"	th	e "conn	ecti	on bet	tweer	n up and bottom"
		fea	ture	S		

												-																	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Û	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Û	0	0	0
0	0	Q	0	Q	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	Ð	Q	0	0	0
Q	0	Q	0	0	¢	0	Q	0	0	0		0	0	0	0	0	0	0	0	0	0	¢	0	Q	Ð	Q	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0			0	0	0		0	0	0	0	0	0	0	0	0	9	0
Q	0	Q	¢	¢	¢	0	Q	0	0	0		0	0	0	Q.	0	0	0	Q	0	0	ø	0	Q	ø	Q	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	•	0
a	0	Q	0	¢	0	0	0	0	0	0		0	0	0	0	0	0	۰	0	0	0	¢	0	0	ø	Q	0	٩	0
Q	0	Q	0	0	0	0	0	0	0	0		0			0	0	0	0	0	0		0	0	0	Ð	Q	0	9	0
0	0	0	0	0	0	0	0.	0.8	0.99	1	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.9	0.	0	0	0	0	0	0	0
0	0	0	0	0	0	0	a.	0.5	0.58	0.58	0.58	0.70	0.89	0.85	0.68	0.58	0.58	0.98	0.99	0.98	0.4	0	0	0	Ð	D	0	8	8
0		0					0	0	0						0	0	0.18	0.98	0.91	0.26		8		0		0			
					1																1		2					1	
9	ľ	0	ľ	ľ	ľ	ľ	2	0	0								0.67	0.90	0.20	0	1	ĉ	ľ	2		0		1	
a	•	0	0	0	0	0	0	0	0	0				0	0	0.30	0.98	6.70	D	0	0	0	0	0	D	Q	0	•	9
0	0	0	0	0	0	0	0	0	0	0				0	0.06	0.79	0.99	0.29	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0				0	0.41	0.99	0.59	6.00	0	0	0	Q	0	0	0	Q	0	0	0
ø	0	0	0	0	0	0	0	0	0	0					0.54	0.99	0.25		0	0	0	Q	0	o	0	Q	0	0	0
0	0	0	0	0	0	0	0	0	0	0				0.07	0.90	0.80	0.01		0	0	0	0	0	0	0	Ø	0	8	0
a		0			•		0	0	0	0				0.41	0.99	0.49	0		0	0		0		0	0	ø	0	e l	8
0	6	0	0	0	0	ō	0	0	0	0				0.54	0.99	0.36	0		0	0	ő	0	ē	0	0	0	0		0
0	0	0	0	0	0	0	0	0	0	0				0.79	0.90	0.10	0		0	0	ē	0	ē	0	0	0	0		0
a	0	0	0	0	0	0	0	0	0	0			0.07	0.91	0.86	0.04	0		0	0		0		0	Ð	D	0		0
0	0	0	0	0	0	0	0	0	0	0		0	0.32	0.99	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			0.43	0.99	0.47	0	0		0	0		0		0	0	0	0	8	0
0	0	0	0	0	0	0	0	0	0	0			0.43	0.99	0.47	0	0		0	0		0	0	0	0	0	0	0	0
0	0	0	0	0	ø	0	0	0	0	0			0.43	0.99	0.47	0	0		0	0	0	0	0	0	Ð	0	0	0	0
Q	0	Q	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0		0	0	0	ø	0	Q	0	Q	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
Q	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	Q	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Û	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Q	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	Q	0	0	Ð	0	0	0	0
Q	0	Q	0	0	¢	0	Q	0	0	0		0	0	0	0	0	0	0	0	0	0	¢	0	Q	Ð	Q	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0
Q	0	Q	¢	0	¢	0	Q	¢	0	0		0	0	0	Q.	0	0	0	Q	0	0	Ģ	0	Q	ø	Q	Q I	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	•	0
g	٥	Q	0	0	0	0	0	0	0	0		0		0	0	0	0	0	0	0	0	¢	0	0	ø	Q	0	•	0
0	۰	Q	0	0	0	0	0	0	0	0					0	0	0		0	0		0	0	0	Ð	Q	0	9	3
Q	0	0	0	0	0	0	0.	0.8	0.99	1	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.9	0	0	0	0	0	0	0	0
0	0	Q	0	0	0	0	a.	0.5	0.58	0.58	0.58	0.75	0.89	0.85	0.68	0.58	0.58	0.98	0.99	0.98	0.4	ø	0	0	Ð	0	0	8	8
0	0	0	0	0	0	0	0	0	0	0				0	0	0	0.18	0.58	0.91	0.26		0		0	0	0	0		0
					ĩ		ĥ										0.67	0.68	0.18	0			ï					1	
	Ľ	ĩ	2	1	1	2	ĩ	ĩ													2	ĩ	2	ĩ	2	Ĩ		1	
	Ľ		ĩ	ĩ	ĩ	ĩ	č											6.70				č	ĩ	2				1	
0	P	0		0	0	•	0	0	0	0					0.06	0.79	0.99	0.23	0	0		0	•	0	0	0	0	1	9
0	0	0	0	0	0	0	0	0	0	0		0			0.41	0.99	0.59	0.00	0	0	0	Q	0	0	0	0	0	٩	0
0	0	0	0	0	0	0	0	0	0	0		0			0.54	0.99	0.25	0	0	0	٥	Q	0	0	0	Q	0	٩	0
0	0	0	0	0	0	0	0	0	0	0	0	0		0.07	0.90	0.80	0.01	0	0	0	٥	0	0	0	0	0	0	0	0
Ø	0	0	0	0	٥	0	0	0	0	0				0.41	0.99	0.49	0		0	0	٥	Ø	0	0	Ð	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0		0.54	0.99	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0		0		0.79	0.99	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0
a	0	Q	0	0	٥	0	0	0	0	0		0	0.07	0.91	0.86	0.04	0	0	0	0	٥	¢	0	0	Ð	Q	0	0	0
0	0	Q	0	0	0	0	0	0	0	0		0	0.32	0.99	0.67	0	0	0	0	0	0	0	0	0	0	Q	0	0	0
0	•	0	0	0	0	0	0	0	0	0			0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	9	0
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0		0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	Ð	0	0	•	9
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0	0	0	0	0	Q	0	0	0	0	0	9	0
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Q	0	0	¢	0	¢	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	¢	0	0	Ð	0	0	¢,	0

Patterns

feature 1

feature 2

												-																	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q	0	Û	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Ű	0	0	0	0	0	0
0	0	Q	0	0	0	0	0	0	0	0		0		0	0	0	0	. 0	0	0	0	Q	0	0	ø	0	0	0	0
Q	0	Q	0	0	0	0	Q	0	0	0		0	0	0	0	0	0		0	0	0	¢	0	Q	Ð	Q	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	. 0	0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	¢	¢	0	Q	¢	0	0		0	0	0	0	0	0		Q	0	0	ø	0	Q	ø	Q	Q	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	٥	Q	0	¢	٥	0	0	0	0	0		0	0	0	0	0	0	•	0	0	0	¢	0	0	ø	Q	0	۰	0
0	٥	Q	0	0	0	0	0	0	0	0		0		0	0	0	0	0	0	0		0	0	0	Ð	0	0	0	0
0	0	0	0	0	0	0	0.	0.8	0.99	1	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.9	0.	0	0	0	0	0	0	0
0	0	0	0	0	0	0	a.	0.5	0.58	0.58	0.58	0.70	0.89	0.85	0.68	0.58	0.58	0.98	0.99	0.98	0.4	0	0	0	0	0	0	0	0
	Ľ				2																								
9	Ľ			ľ		ľ	~												0.81	0.20	1	Ÿ	ľ	~		9		1	
0	P	Q	0	0	0	0	0	0	0	0					0	0	0.67	0.98	0.28	0	0	Q	0	0	0	Q	0	9	9
a	0	Û	0	Û	¢	0	0	0	0	0	0	0	0	0	0	0.30	0.98	6.70	0	0	¢	Ô	0	0	Ð	Ø	0	٥	0
0	0	0	0	0	0	0	0	0	0	0				0	0.06	0.79	0.99	0.29	0	0	0	0	0	0	0	0	0	0	0
0		0	0	0	0	0	0	0	0	0					0.41	0.99	0.59	0.00	0	0		0		0	0	0	0	0	0
0		0					0	0	0	0					0.54	0.99	0.25		D	0				0		0			0
	Ľ			1	2	2															1	1	2	1	2	2	2	1	
0	Ľ	0		9	•	•	0	0	0	0				0.07	0.90	0.80	6.01		0	0		0	•	0		0	0	1	
0	0	0	0	0	0	0	0	0	0	0		0		0.41	0.99	0.49	0		0	0	0	0	0	0	ø	0	0	•	0
0	0	Q	0	0	0	0	0	0	0	0		0		0.54	0.99	0.36	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	0.79	0.99	0.10	0		0	0	0	0	0	0	0	0	0	0	9
9	2	Q	0	0	0	0	0	0	0	0			o.ar	0.91	0.86	0.04	0		Q	0		0	0	0	D	0	0	2	0
0	2	Q	0	0	0	0	0	0	0	0			0.32	0.99	0.67	0	0		0	0		0	0	0	0	Q	0	2	0
0	2	0			0	2	0	0	0	0			0.43	0.99	0.47	0	0		0	0	2	0	2	0	0	0	0	2	9
0	Ľ	0		2	2	2	0	0	0	0			0.43	0.99	0.47	0	0		0	0	2	0	2	0	0	0	0	2	
9	Ľ	0				2	0	0	0	9			0.43	0.99	0.47	0	0		0	0	2	0	2	0	0	0	9	2	-
9	Ľ	0			-	2	0	0	0	9			0.43	0.99	0.47	0	0		0	0		9	2	0		9	9	2	-
9	Ľ	0			-	2	0	0	0				0.43	0.99	0.47	0	0		0	0	1	0	2	0		0		1	-
9	Ļ	0	-	-	-	-	0	0	0	9	-	-	0.43	0.90	0.47	0	0		0	0	-	0	-	0	0	0	0	4	-
Q	0	Q	0	Q	ę	0	0	0	0	0					0	0	0		0	0	0	Ģ	0	Q	Ð	Q	Q	0	0

Patterns

feature 1

feature 2

												-																	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q	0	Û	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Ű	0	0	0	0	0	0
0	0	Q	0	0	0	0	0	0	0	0		0		0	0	0	0	. 0	0	0	0	Q	0	0	ø	0	0	0	0
Q	0	Q	0	0	0	0	Q	0	0	0		0	0	0	0	0	0		0	0	0	¢	0	Q	Ð	Q	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	. 0	0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	¢	¢	0	Q	¢	0	0		0	0	0	0	0	0		Q	0	0	ø	0	Q	ø	Q	Q	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	٥	Q	0	¢	٥	0	0	0	0	0		0	0	0	0	0	0	•	0	0	0	¢	0	0	ø	Q	0	۰	0
0	٥	Q	0	0	0	0	0	0	0	0		0		0	0	0	0	0	0	0		0	0	0	Ð	0	0	0	0
0	0	0	0	0	0	0	0.	0.8	0.99	1	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.9	0.	0	0	0	0	0	0	0
0	0	0	0	0	0	0	a.	0.5	0.58	0.58	0.58	0.70	0.89	0.85	0.68	0.58	0.58	0.98	0.99	0.98	0.4	0	0	0	0	0	0	0	0
	Ľ				2																								
9	Ľ			ľ		ľ	~												0.81	0.20	1	Ÿ	ľ	~		9		1	
0	P	Q	0	0	0	0	0	0	0	0					0	0	0.67	0.98	0.28	0	0	Q	0	0	0	Q	0	9	9
a	0	Û	0	Û	¢	0	0	0	0	0	0	0	0	0	0	0.30	0.98	6.70	0	0	¢	Ô	0	0	Ð	Ø	0	٥	0
0	0	0	0	0	0	0	0	0	0	0				0	0.06	0.79	0.99	0.29	0	0	0	0	0	0	0	0	0	0	0
0		0	0	0	0	0	0	0	0	0					0.41	0.99	0.59	0.00	0	0		0		0	0	0	0	0	0
0		0					0	0	0	0					0.54	0.99	0.25		D	0				0		0			0
	Ľ			1	2	2															1	1	2	1	2	2	2	1	
0	Ľ	0		9	•	•	0	0	0	0				0.07	0.90	0.80	6.01		0	0		0	•	0		0	0	1	
0	0	0	0	0	0	0	0	0	0	0		0		0.41	0.99	0.49	0	•	0	0	0	0	0	0	ø	0	0	•	0
0	0	Q	0	0	0	0	0	0	0	0		0		0.54	0.99	0.36	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	0.79	0.99	0.10	0		0	0	0	0	0	0	0	0	0	0	9
9	2	Q	0	0	0	0	0	0	0	0			o.ar	0.91	0.86	0.04	0		Q	0		0	0	0	D	0	0	2	0
0	2	Q	0	0	0	0	0	0	0	0			0.32	0.99	0.67	0	0		0	0		0	0	0	0	Q	0	2	0
0	2	0			0	2	0	0	0	0			0.43	0.99	0.47	0	0		0	0	2	0	2	0	0	0	0	2	9
0	Ľ	0		2	2	2	0	0	0	0			0.43	0.99	0.47	0	0		0	0	2	0	2	0	0	0	0	2	
9	Ľ	0				2	0	0	0	9			0.43	0.99	0.47	0	0		0	0	2	0	2	0	0	0	9	2	-
9	Ľ	0			-	2	0	0	0	0			0.43	0.99	0.47	0	0		0	0		9	1	0		9	9	2	-
9	Ľ	0			-	2	0	0	0				0.43	0.99	0.47	0	0		0	0	1	0	2	0		0		1	-
9	Ļ	0	-	-	-	-	0	0	0	9	-	-	0.43	0.90	0.47	0	0		0	0	-	0	-	0	0	0	0	4	-
Q	0	Q	0	Q	ę	0	0	0	0	0					0	0	0		0	0	0	Ģ	0	Q	Ð	Q	Q	0	0

Patterns

feature 1

feature 2

0	0	0	0	0	0	0	0	0	0	0	0	0	- 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Û	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Q	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	Q	0	0	Ð	0	0	0	0
Q	0	Q	0	0	¢	0	Q	0	0	0		0	0	0	0	0	0	0	0	0	0	¢	0	Q	Ð	Q	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0
Q	0	Q	¢	0	¢	0	Q	¢	0	0		0	0	0	Q.	0	0	0	Q	0	0	Ģ	0	Q	ø	Q	Q I	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	•	0
g	٥	Q	0	0	0	0	0	0	0	0		0		0	0	0	0	0	0	0	0	¢	0	0	ø	Q	0	•	0
0	۰	Q	0	0	0	0	0	0	0	0					0	0	0		0	0		0	0	0	Ð	Q	0	9	3
Q	0	0	0	0	0	0	0.	0.8	0.99	1	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.9	0	0	0	0	0	0	0	0
0	0	Q	0	0	0	0	a.	0.5	0.58	0.58	0.58	0.75	0.89	0.85	0.68	0.58	0.58	0.98	0.99	0.98	0.4	ø	0	0	Ð	0	0	8	8
0	0	0	0	0	0	0	0	0	0	0				0	0	0	0.18	0.58	0.91	0.26		0		0	0	0	0		0
	Ľ,				ĩ		ĥ										0.67	0.68	0.18	0			ï					1	
	Ľ	ĩ	2	1	1	2	ĩ	ĩ													2	ĩ	2	ĩ	2	Ĩ		1	
	Ľ		ĩ	ĩ	ĩ	ĩ	č											6.70				č	ĩ	2				1	
0	P	0		0	0	•	0	0	0	0					0.06	0.79	0.99	0.23	0	0		0	•	0	0	0	0	1	9
0	0	0	0	0	0	0	0	0	0	0		0			0.41	0.99	0.59	0.00	0	0	0	Q	0	0	0	0	0	٩	0
0	0	0	0	0	0	0	0	0	0	0		0			0.54	0.99	0.25	0	0	0	٥	Q	0	0	0	Q	0	٩	0
0	0	0	0	0	0	0	0	0	0	0	0	0		0.07	0.90	0.80	0.01	0	0	0	٥	0	0	0	0	0	0	0	0
Ø	0	0	0	0	٥	0	0	0	0	0				0.41	0.99	0.49	0		0	0	٥	Ø	0	0	Ð	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0		0.54	0.99	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0		0		0.79	0.99	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0
a	0	Q	0	0	٥	0	0	0	0	0		0	0.07	0.91	0.86	0.04	0	0	0	0	٥	¢	0	0	Ð	Q	0	0	0
0	0	Q	0	0	0	0	0	0	0	0		0	0.32	0.99	0.67	0	0	0	0	0	0	0	0	0	0	Q	0	0	0
0	•	0	0	0	0	0	0	0	0	0			0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	9	0
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0			0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	Ð	0	0	•	9
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0	0	0	0	0	Q	0	0	0	0	0	9	0
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Q	0	0	¢	0	¢	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	¢	0	0	Ð	0	0	¢,	0

Patterns

feature 1

feature 2

0	0	0	0	0	0	0	0	0	0	0	0	0	- 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Û	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Q	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	Q	0	0	Ð	0	0	0	0
Q	0	Q	0	0	¢	0	Q	0	0	0		0	0	0	0	0	0	0	0	0	0	¢	0	Q	Ð	Q	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0
Q	0	Q	¢	0	¢	0	Q	¢	0	0		0	0	0	Q.	0	0	0	Q	0	0	Ģ	0	Q	ø	Q	Q I	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	•	0
g	٥	Q	0	0	0	0	0	0	0	0		0		0	0	0	0	0	0	0	0	¢	0	0	ø	Q	0	•	0
0	۰	Q	0	0	0	0	0	0	0	0					0	0	0		0	0		0	0	0	Ð	Q	0	9	3
Q	0	0	0	0	0	0	0.	0.8	0.99	1	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.9	0	0	0	0	0	0	0	0
0	0	Q	0	0	0	0	a.	0.5	0.58	0.58	0.58	0.75	0.89	0.85	0.68	0.58	0.58	0.98	0.99	0.98	0.4	ø	0	0	Ð	0	0	8	8
0	0	0	0	0	0	0	0	0	0	0				0	0	0	0.18	0.58	0.91	0.26		0		0	0	0	0		0
					ĩ		ĥ										0.67	0.68	0.18	0			ï					1	
	Ľ	ĩ	2	1	1	2	ĩ	ĩ													2	ĩ	2	ĩ	2	Ĩ		1	
	Ľ		ĩ	ĩ	ĩ	ĩ	č											6.70				č	ĩ	2				1	
0	P	0		0	0	•	0	0	0	0					0.06	0.79	0.99	0.23	0	0		0	•	0	0	0	0	1	9
0	0	0	0	0	0	0	0	0	0	0		0			0.41	0.99	0.59	0.00	0	0	0	Q	0	0	0	0	0	٩	0
0	0	0	0	0	0	0	0	0	0	0		0			0.54	0.99	0.25	0	0	0	٥	Q	0	0	0	Q	0	٩	0
0	0	0	0	0	0	0	0	0	0	0	0	0		0.07	0.90	0.80	0.01	0	0	0	٥	0	0	0	0	0	0	0	0
Ø	0	0	0	0	٥	0	0	0	0	0				0.41	0.99	0.49	0		0	0	٥	Ø	0	0	Ð	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0		0.54	0.99	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0		0		0.79	0.99	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0
a	0	Q	0	0	٥	0	0	0	0	0		0	0.07	0.91	0.86	0.04	0	0	0	0	٥	¢	0	0	Ð	Q	0	0	0
0	0	Q	0	0	0	0	0	0	0	0		0	0.32	0.99	0.67	0	0	0	0	0	0	0	0	0	0	Q	0	0	0
0	•	0	0	0	0	0	0	0	0	0			0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	9	0
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0			0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	Ð	0	0	•	9
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0	0	0	0	0	Q	0	0	0	0	0	9	0
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Q	0	0	¢	0	¢	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	¢	0	0	Ð	0	0	¢,	0

Patterns

feature 1

												-																	
0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a	0	Û	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Q	0	Q	0	0	0	0	0	0		0		0	0	0	0		0	0	0	Q	0	0	0	0	0	0	0
Q	0	Q	0	0	0	0	Q	0	0	0		0	0	0	0	0	0		0	0	0	¢	0	Q	0	Q	Q	0	0
0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	. 0	0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	¢	¢	0	Q	0	0	0		0	0	0	Q.	0	0	0	0	0	0	¢	0	Q	ø	Q	Q	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q	٥	Q	0	¢	٥	0	0	0	0	0		0	0	0	0	0	0	•	0	0	٥	¢	٥	0	ø	0	Q	٥	0
0	0	Q	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	0	Ð	0	0	0	0
0	0	0	0	0	0	0	0.	0.8	0.99	1	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.9	0.	0	0	0	0	0	0	0
0		0		0			а.	0.5	0.58	0.58	0.58	0.70	0.69	0.85	0.68	0.58	0.58	0.98	0.99	0.96	0.4	0		0	0	0	0		0
				2	2	2																	2	2	2	2			
9	•	Q		•	•	٩	0	0	0	9					0		0.18	C. NO	0.91	0.26		9	•	0		0	9	1	
Q	0	Q	0	Q	¢	0	0	0	0	0		0	0	0	0	0	0.47	0.98	0.28	0	0	Q	0	Q	ø	0	Q	0	0
a	0	Û	0	0	0	0	0	0	0	0		0		0	0	0.30	0.98	6.70	0	0	٥	ø	0	0	0	0	0	0	0
0		0		0	•		0	0	0	0					0.06	0.79	0.99	0.29	0	0		0		0	0	0	0		0
				ĩ											0.41							,		2					
×	ľ	č	ĩ	ĩ	ĩ	ĩ	č														1	ľ	ĩ	č	ĩ			1	
9	•	Q		9	ę	6	0	0	0	9					0.54	0.99	0.25		0	0		Q	۰	0	0	0	0	*	9
0	0	0	0	0	0	0	0	0	0	0	0	0		0.07	0.90	0.80	0.01	0	0	0	0	0	0	0	ø	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0				0.41	0.99	0.49	0		0	0	٥	ø	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0	. 0	0.54	0.99	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0		0	. 0	0.79	0.99	0.10	0		0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	0	٥	0	0	0	0	0		0	0.07	0.91	0.86	0.04	0	0	0	0	٥	¢	0	0	Ð	Q	0	0	0
0	0	Q	0	0	0	0	0	0	0	0		0	0.32	0.99	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			0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	0	¢	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	Ø	0	0	Ð	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Q	0	¢	¢	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	¢	0	0	Ð	0	0	0	0

Patterns

feature 1

												-																	
0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a	0	Û	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Q	0	Q	0	0	0	0	0	0		0		0	0	0	0		0	0	0	Q	0	0	0	0	0	0	0
Q	0	Q	0	0	0	0	Q	0	0	0		0	0	0	0	0	0		0	0	0	¢	0	Q	0	Q	Q	0	0
0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	. 0	0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	¢	¢	0	Q	0	0	0		0	0	0	Q.	0	0	0	0	0	0	¢	0	Q	ø	Q	Q	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q	٥	Q	0	¢	٥	0	0	0	0	0		0	0	0	0	0	0	•	0	0	٥	¢	٥	0	ø	0	Q	٥	0
0	0	Q	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	0	Ð	0	0	0	0
0	0	0	0	0	0	0	0.	0.8	0.99	1	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.9	0.	0	0	0	0	0	0	0
0		0		0			а.	0.5	0.58	0.58	0.58	0.70	0.69	0.85	0.68	0.58	0.58	0.98	0.99	0.96	0.4	0		0	0	0	0		0
				2	2	2																	2	2	2	2			
9	•	Q		•	•	٩	0	0	0	9					0		0.18	0.96	0.91	0.26		9	•	0		0	9	1	
Q	0	Q	0	Q	¢	0	0	0	0	0		0	0	0	0	0	0.47	0.98	0.28	0	0	Q	0	Q	ø	0	Q	0	0
a	0	Û	0	0	0	0	0	0	0	0		0		0	0	0.30	0.98	6.70	0	0	٥	ø	0	0	0	0	0	0	0
0		0		0	•		0	0	0	0					0.06	0.79	0.99	0.29	0	0		0		0	0	0	0		0
				ĩ											0.41							,		2					
×	ľ	č	ĩ	ĩ	ĩ	ĩ	č														1	ľ	ĩ	č	ĩ			1	
9	•	Q		9	ę	6	0	0	0	9					0.54	0.99	0.25		0	0		Q	۰	0	0	0	0	*	9
0	0	0	0	0	0	0	0	0	0	0	0	0		0.07	0.90	0.80	0.01	0	0	0	0	0	0	0	ø	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0				0.41	0.99	0.49	0		0	0	٥	ø	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0	. 0	0.54	0.99	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0		0		0.79	0.99	0.10	0		0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	0	٥	0	0	0	0	0		0	0.07	0.91	0.86	0.04	0	0	0	0	٥	¢	0	0	Ð	Q	0	0	0
0	0	Q	0	0	0	0	0	0	0	0		0	0.32	0.99	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			0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	0	¢	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	Ø	0	0	Ð	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Q	0	¢	¢	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	¢	0	0	Ð	0	0	0	0

Patterns

feature 1

												-																	
0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a	0	Û	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Q	0	Q	0	0	0	0	0	0		0		0	0	0	0	0	0	0	0	Q	0	0	0	0	0	0	0
Q	0	Q	0	0	0	0	Q	0	0	0		0	0	0	0	0	0		0	0	0	¢	0	Q	0	Q	Q	0	0
0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	. 0	0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	¢	¢	0	Q	0	0	0		0	0	0	Q.	0	0	0	0	0	0	¢	0	Q	ø	Q	Q	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q	٥	Q	0	¢	٥	0	0	0	0	0		0	0	0	0	0	0	•	0	0	٥	¢	٥	0	ø	0	Q	٥	0
0	0	Q	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	0	Ð	0	0	0	0
0	0	0	0	0	0	0	0.	0.8	0.99	1	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.9	0.	0	0	0	0	0	0	0
0		0		0			а.	0.5	0.58	0.58	0.58	0.70	0.69	0.85	0.68	0.58	0.58	0.98	0.99	0.96	0.4	0		0	0	0	0		0
				2	2	2																	2	2	2	2			
9	•	Q		•	•	٩	0	0	0	9					0		0.18	C. NO	0.91	0.26		9	•	0		0	9	1	
Q	0	Q	0	Q	¢	0	0	0	0	0		0	0	0	0	0	0.67	0.98	0.28	0	0	Q	0	Q	ø	0	Q	0	0
a	0	Û	0	0	0	0	0	0	0	0		0		0	0	0.30	0.98	6.70	0	0	٥	ø	0	0	0	0	0	0	0
0		0		0	•		0	0	0	0					0.06	0.79	0.99	0.29	0	0		0		0	0	0	0		0
				ĩ											0.41							,		2					
×	ľ	č	ĩ	ĩ	ĩ	ĩ	č														1	ľ	ĩ	č	ĩ			1	
9	•	Q		9	ę	6	0	0	0	9					0.54	0.99	0.25		0	0		Q	۰	0	0	0	0	*	9
0	0	0	0	0	0	0	0	0	0	0	0	0		0.07	0.90	0.80	0.01	0	0	0	0	0	0	0	ø	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0				0.41	0.99	0.49	0		0	0	٥	ø	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0	. 0	0.54	0.99	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0		0		0.79	0.99	0.10	0		0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	0	٥	0	0	0	0	0		0	0.07	0.91	0.86	0.04	0	0	0	0	٥	¢	0	0	Ð	Q	0	0	0
0	0	Q	0	0	0	0	0	0	0	0		0	0.32	0.99	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			0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	0	¢	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	Ø	0	0	Ð	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Q	0	¢	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	¢	0	0	Ð	0	0	0	0

Patterns

feature 1

												-																	
0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Û	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Q	0	Q	0	0	0	0	0	0		0		0	0	0	0		0	0	0	Q	0	0	0	0	0	0	0
Q	0	Q	0	0	0	0	Q	0	0	0		0	0	0	0	0	0		0	0	0	¢	0	Q	0	Q	Q	0	0
0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	. 0	0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	¢	¢	0	Q	0	0	0		0	0	0	Q.	0	0	0	0	0	0	¢	0	Q	ø	Q	Q	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q	٥	Q	0	¢	٥	0	0	0	0	0		0	0	0	0	0	0	•	0	0	٥	¢	٥	0	ø	0	Q	٥	0
0	0	Q	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0		0	0	0	Ð	0	0	0	0
0	0	0	0	0	0	0	0.	0.8	0.99	1	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.9	0.	0	0	0	0	0	0	0
0		0		0			a.	0.5	0.58	0.58	0.58	0.70	0.69	0.85	0.68	0.58	0.58	0.98	0.99	0.96	0.4	0		0	0	0	0		0
				2	2	2																	2	2	2	2			
9	•	Q		•	•	٩	0	0	0	9					0		0.18	C. NO	0.91	0.26		9	•	0		0	9	1	
Q	0	Q	0	Q	¢	0	0	0	0	0		0	0	0	0	0	0.47	0.98	0.28	0	0	Q	0	Q	ø	0	Q	0	0
a	0	Û	0	0	0	0	0	0	0	0		0		0	0	0.30	0.98	6.70	0	0	٥	ø	0	0	0	0	0	0	0
0		0		0	•		0	0	0	0					0.06	0.79	0.99	0.29	0	0		0		0	0	0	0	•	0
				ĩ											0.41							,		2					
×	ľ	č	ĩ	ĩ	ĩ	ĩ	č														1	ľ	ĩ	č	ĩ			1	
9	•	Q		9	ę	6	0	0	0	9					0.54	0.99	0.25		0	0		Q	۰	0	0	0	0	*	9
0	0	0	0	0	0	0	0	0	0	0	0	0		0.07	0.90	0.80	0.01	0	0	0	0	0	0	0	ø	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0				0.41	0.99	0.49	0		0	0	٥	ø	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0	. 0	0.54	0.99	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	٥	0	0	0	0	0		0		0.79	0.99	0.10	0		0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	0	٥	0	0	0	0	0		0	0.07	0.91	0.86	0.04	0	0	0	0	٥	¢	0	0	Ð	Q	0	0	0
Q	0	Q	0	0	0	0	0	0	0	0		0	0.32	0.99	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			0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0		0	0.43	0.99	0.47	0	0		0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q	0	Q	0	0	¢	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	Ø	0	0	Ð	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.43	0.99	0.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	Q	0	¢	¢	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	¢	0	0	Ð	0	0	0	0

Patterns

feature 1

feature 2

It is a "7"

Neural Network is an algorithm used to recognize patterns in data. Convolutional Neural Network uses convolutions to extract image features and recognize feature patterns.

Neural Network is an algorithm used to recognize patterns in data.

Extract image features -> find feature patterns for each category

Convolutional Neural Network uses convolutions to extract image features and recognize feature patterns.

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

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

Edges
















Edges Corners

















Edges Corners Lines

















Edges Corners Lines Circles

















Edges Corners Lines Circles

. . .

















Edges Corners Lines Circles

Basic Features

. . .







Columns



Columns Statues



Columns Statues

...



Columns Statues

- - -

Complex Features



Features in different levels



Faces



Chairs

















blur

























Feature map Different processed versions of the original images



1	٢	2	٢	1	(\$)
0.7	•	-1.2		0.7	٢
-1		-2	•	-1.9	•
	(custom	1	\$	

Change the kernel values



1	٢	2	٢	1	(\$)
0.7	•	-1.2		0.7	٢
-1		-2	•	-1.9	•
	(custom	1	\$	

Change the kernel values















Adjust the weights according to the <u>recognition performance</u> (A CALLER





Feature map changes until weights adjusting finished




























Model

- Num of layers (stages)
- Num of channels (filters) in each layer







https://poloclub.github.io/cnn-explainer/#article-convolution







Scores on different categories

https://poloclub.github.io/cnn-explainer/#article-convolution



Features





https://poloclub.github.io/cnn-explainer/#article-convolution





Pooling Layer (reduce the resolution)



Flatten Layer (Convert 2D data to 1D for neural nets)



























Fully-Connected Layer Neural Nets for pattern recognition













conv_2_1 (28, 28, 10)	relu_2_1 (28, 28, 10)	conv_2_2 (26, 26, 10)	relu_2_2 (26, 26, 10)	max_pool_2 (13, 13, 10)	output (10)
1			1		lifeboat
			÷		ladybug
12			1		pizza
*	•		4		bell pepper
			*	:	school bus
			7	;	koala
			*		espresso
			+	•	red panda
					orange
			*	-	sport car
-4.64 0	.00 4.64	-5.84	0.00	5.84	0.0 0.8