# MATLAB EXPO 2018 UNITED KINGDOM

3 October | Silverstone, Northamptonshire

Register at matlabexpo.co.uk

# MATLAB EXPO 2018

Image Processing and Computer Vision with MATLAB

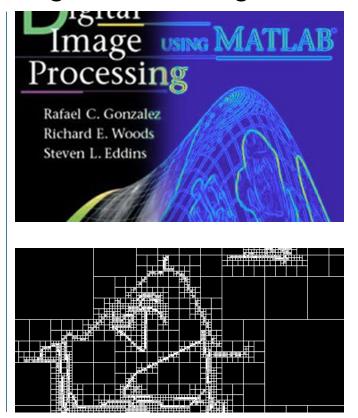
Justin Pinkney





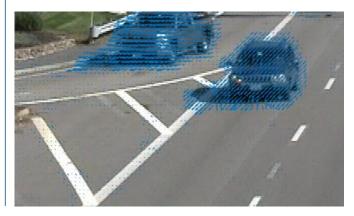
# Image Processing, Computer Vision, and Deep Learning

#### Image Processing



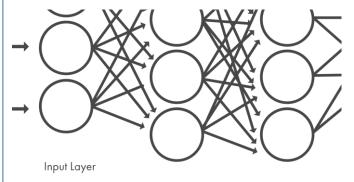
#### **Computer Vision**





#### **Deep Learning**









# **Deep Learning vs Image Processing**

The perception:

"Deep learning has made 'traditional' image processing obsolete."

or

"Deep learning needs millions of examples and is only good for classifying pictures of cats anyway."



# **Deep Learning and Image Processing**

The reality:

Deep learning and image processing are effective tools to solve different problems.

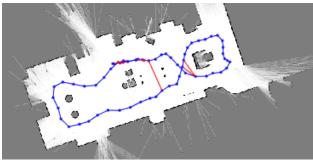
and

Computer Vision tasks are complex, use the right tool for the job.



### What are real world problems like?

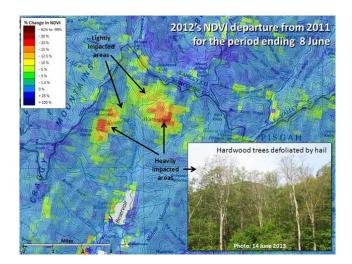








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# **An Example**

5 6	3			7				
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	9	8					6	
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8 4 7			8		3			1
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	6					2	8	
			4	1	9			5
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The Sydney Morning Herald

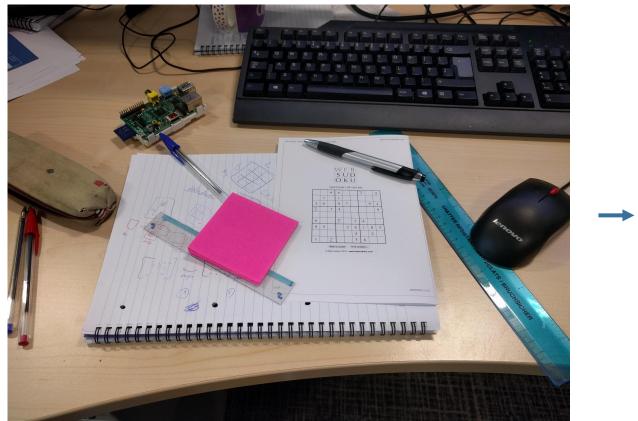
# The game's up: jurors playing Sudoku abort trial

By Malcolm Knox 11 June 2008 – 10:00am

AFTER 105 witnesses and three months of evidence, a drug trial costing \$1 million was aborted vesterday when it emerged that jurors had been playing Sudoku since the trial's second week



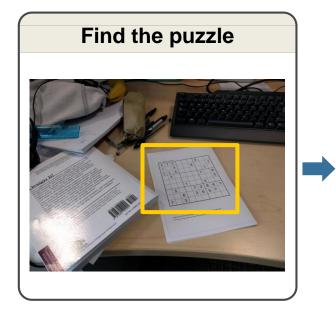
# Take a picture → Solve the puzzle



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



### **Breaking down the problem**



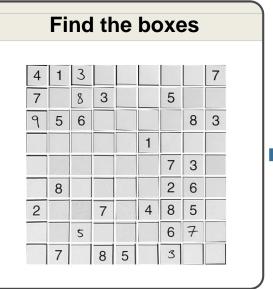
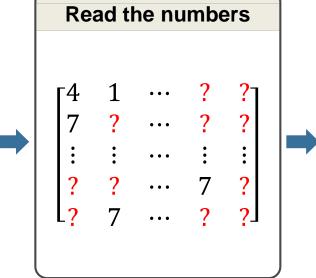
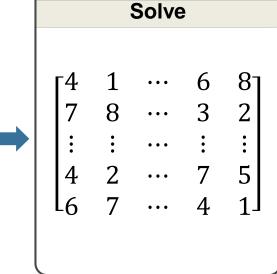


Image Processing





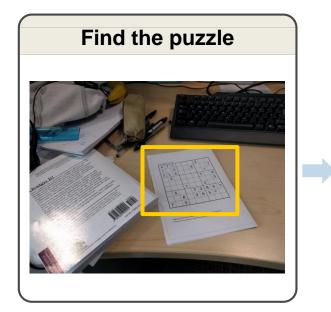
Deep Learning

Optimisation

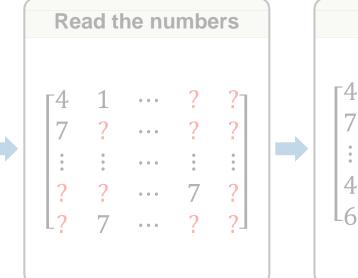
**Deep Learning** 

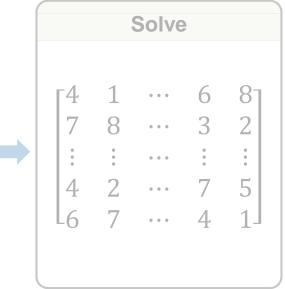


# **Step 1 – Find the puzzle**



4	1	3						7
7		8	3			5		
9	5	6					8	3
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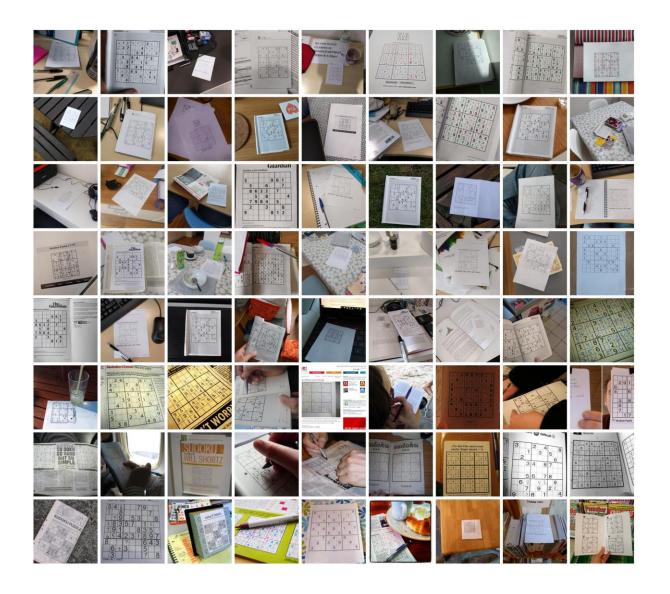






# **Step 1 – Find the puzzle**

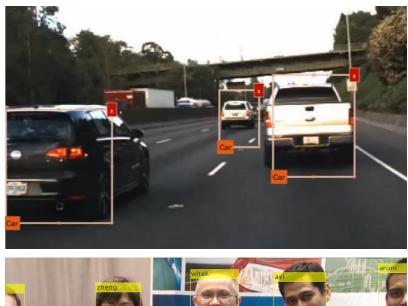
- Varied background and object of interest
- Uncontrolled image acquisition
- Good problem for deep learning





# Finding things with deep learning

#### **Object detection**



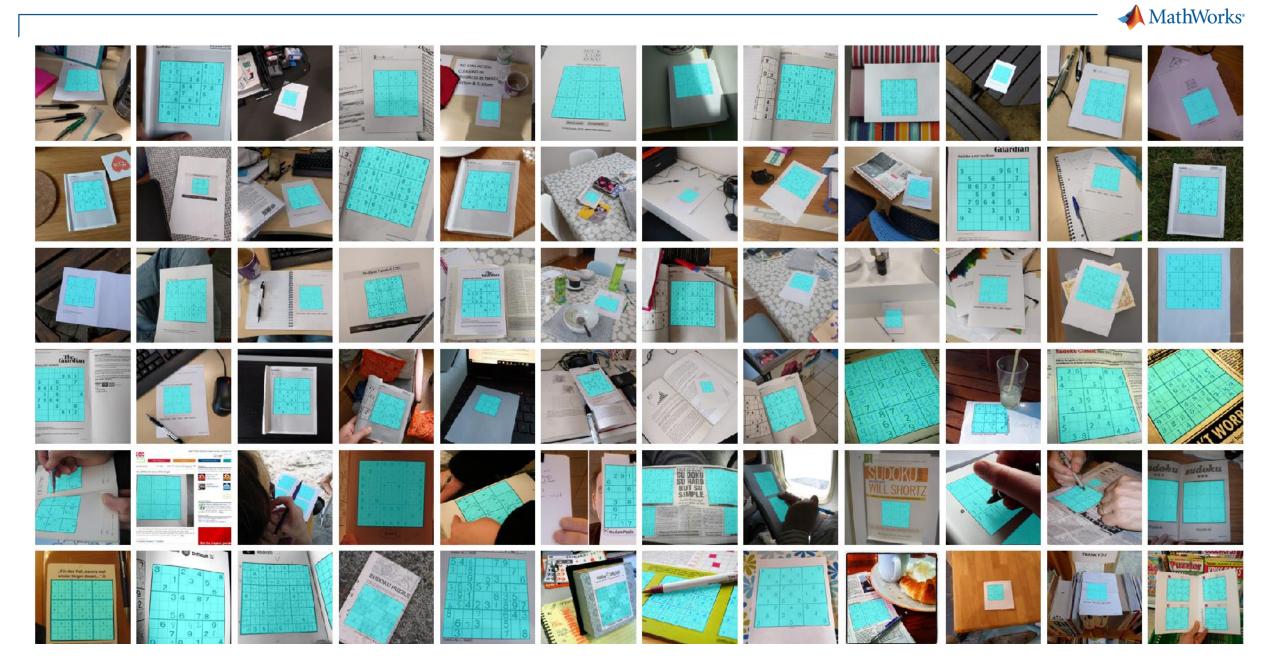


#### Semantic segmentation



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Define New ROI Label To label an ROI, you must first define one or more of the following label types: - Rectangle label - Pixel label		Load images to start labeling.					
Scene Label Definition Define new scene label							
Apply to Image Remove from Image							
To label a scene, you must first define a scene label.							





### How do we train a semantic segmentation network?

 Manage input data and apply pre-processing

- Use a well established network architecture configured for our problem
- Set up training options

Train the network

```
%% Setup the network
numClasses = 2;
baseNetwork = 'vgg16';
layers = segnetLayers(inputSize, numClasses, baseNetwork);
layers = sudoku.weightLossByFrequency(layers, train);
```

```
%% Set up the training options
opts = trainingOptions('sgdm', ...
'InitialLearnRate', 0.01, ...
'ValidationData', test, ...
'MaxEpochs', 10, ...
'Plots', 'training-progress');
```

%% Train
net = trainNetwork(train, layers, opts);

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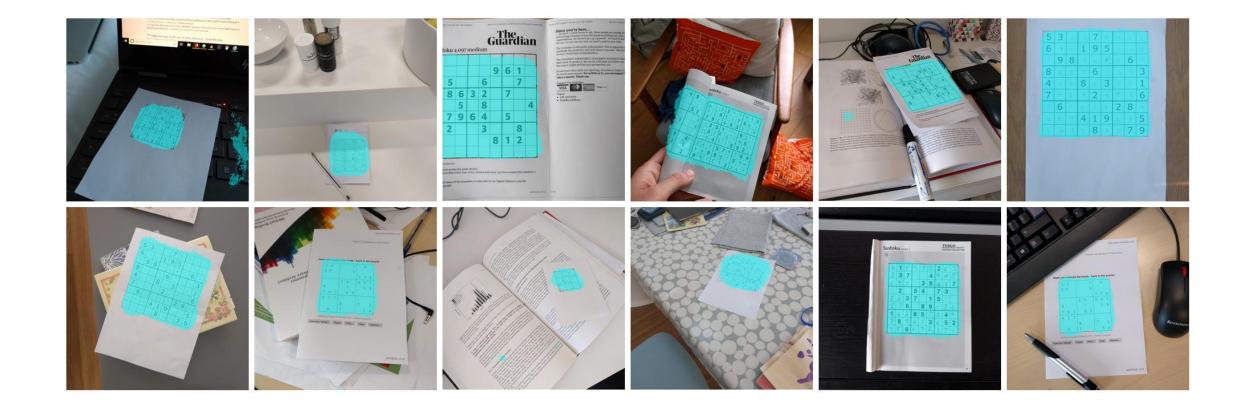


Figure 7.18. Five distinct network types containing 100 individuals These are loss then the figure 7.18. Five distinct network types (middle row), Lattice, and Small-World (here the Figure 7.18. Five distinct network of a middle row), Lattice, and Small-Work man the Random. Spatial (top row), Scale-Free networks all use the same position of individual Random. Spatial (top row), scale-free networks all use the same position of individuals in meters of a material Random, Spatial, and Scale-Free networks the position of the individuals is irrelevant for the state of the state Random, Spatial, and Scale-Free network, the position of the individuals is irrelevant in formany and Random and Scale-Free network, the position of the individuals is approximately a second Random and Scale-Free network, on port contacts per individual is approximately 4 For the In all five graphs, the average number of contacts are shaded gray. In all five graphs, the average numbers of contacts are shaded gray network, individuals with high numbers of contacts are shaded gray.

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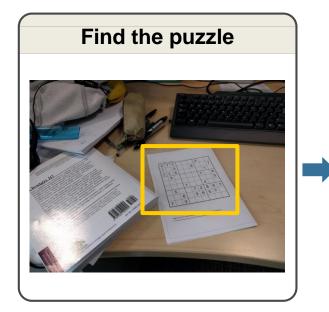
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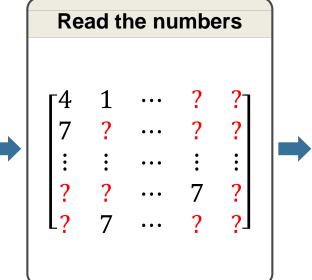
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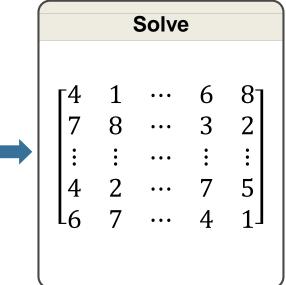


### An Example – Sudoku Solver



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

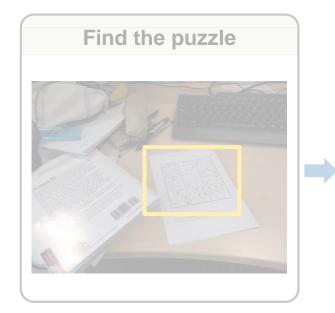


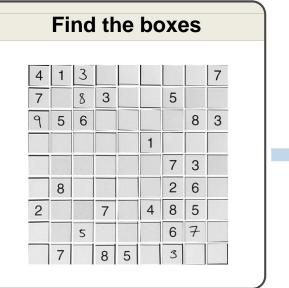


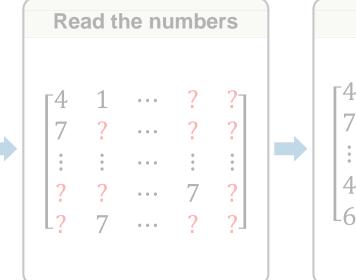
**Deep Learning** 

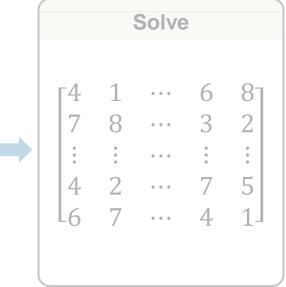


# **Step 2 – Find the boxes**





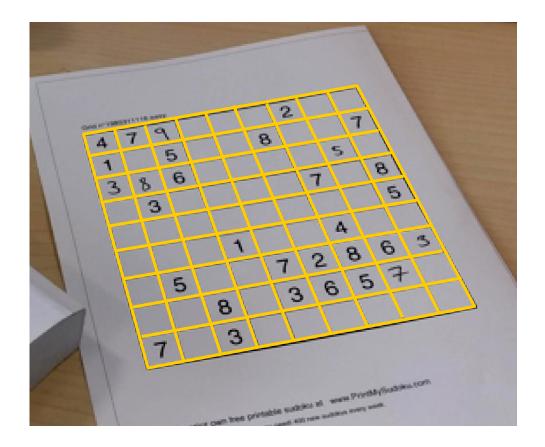






# **Step 2 – Find the boxes**

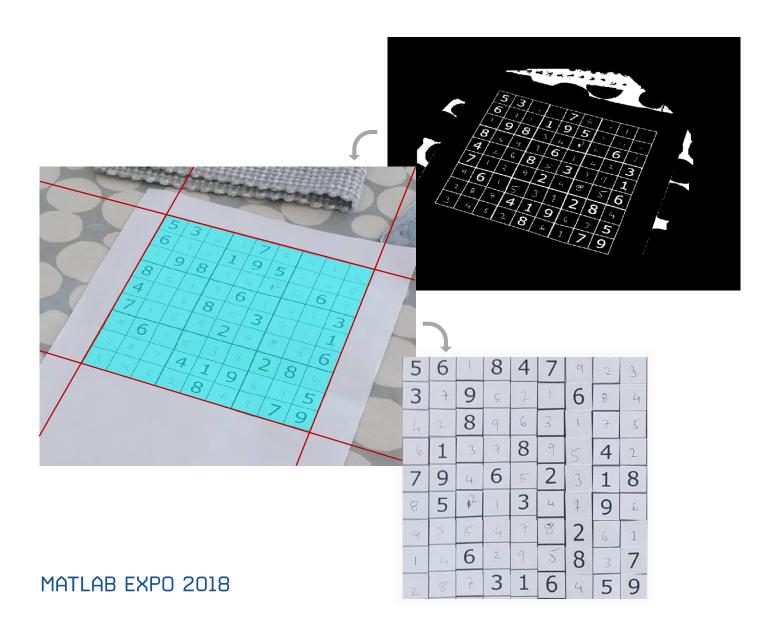
- Well defined problem:
  - 4 intersecting straight lines
  - Dark ink on light paper
  - Grid of 9 x 9 equally sized boxes
- Need good precision to localise individual boxes.
- Good image processing problem.



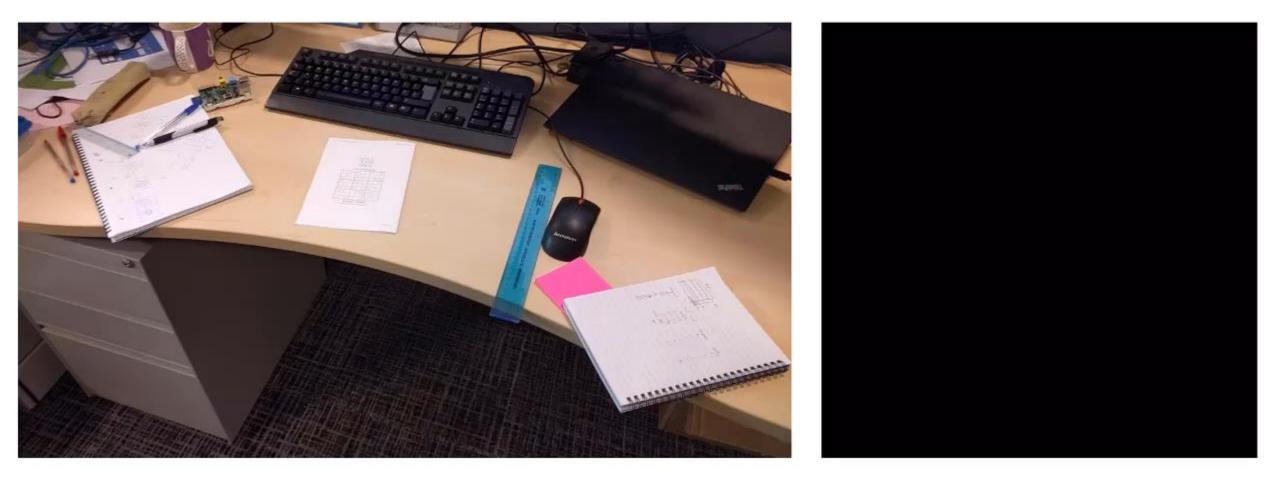
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### **Step 2 – Find the boxes**



# Image processing pipeline Adaptive thresholding imbinarize Morphological operations imopen/imclose Region property analysis regionprops Robust line detection hough/houghpeaks Geometric warping fitgeotrans/imwarp





Solve

• • •

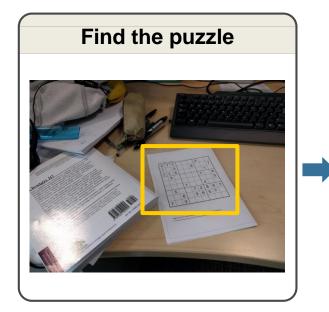
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### An Example – Sudoku Solver



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

**Read the numbers** 

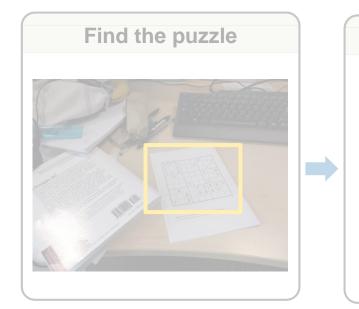
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Image Processing

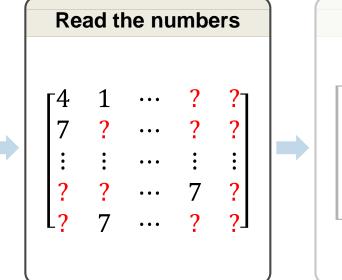
**Deep Learning** 

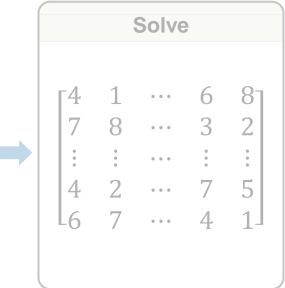


# **Step 3 – Read the numbers**



4	1	3						7
7		8	3			5		
9	5	6					8	3
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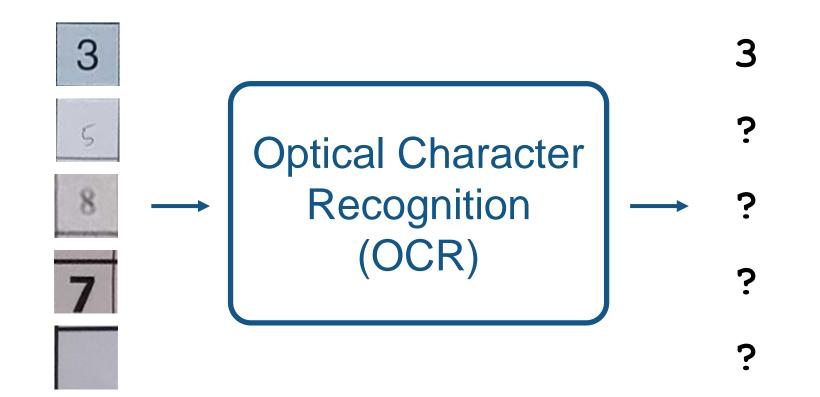
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# **Step 3 – Read the numbers**

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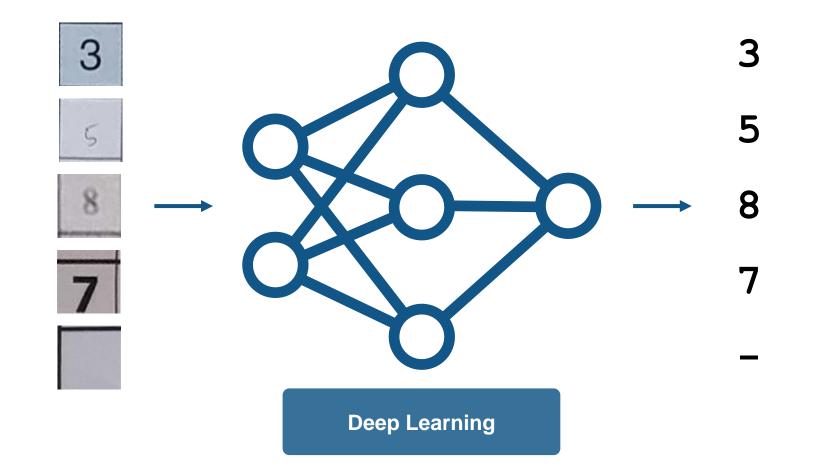


### How can we read numbers?



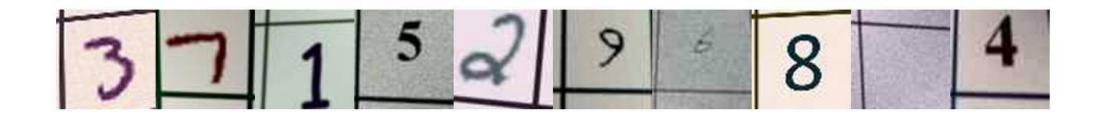


#### How can we read numbers?





# We can make synthetic training data



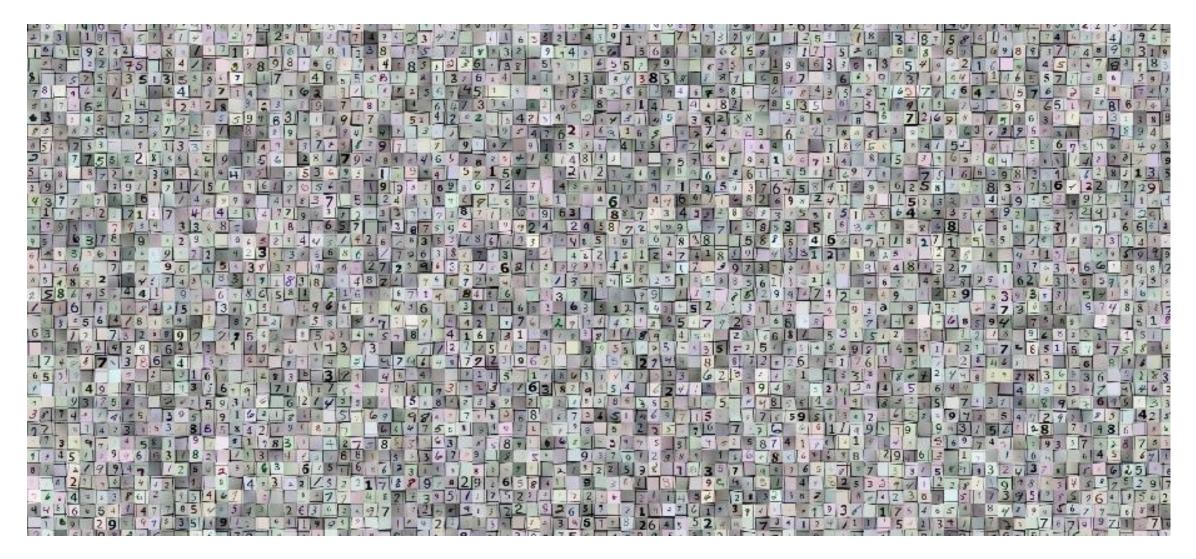


### We can make (lots of) synthetic training data





### We can make (lots of) synthetic training data



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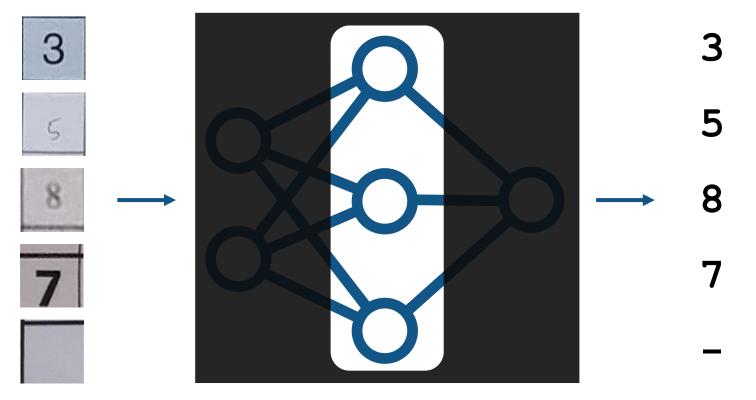
# **Debugging a network**



97.8% accuracy



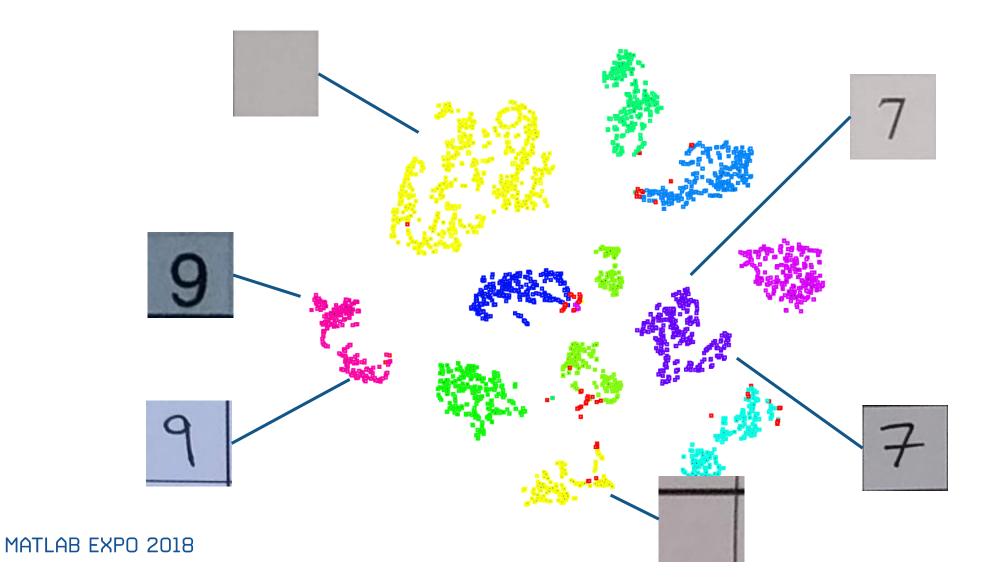
## **Debugging a network**

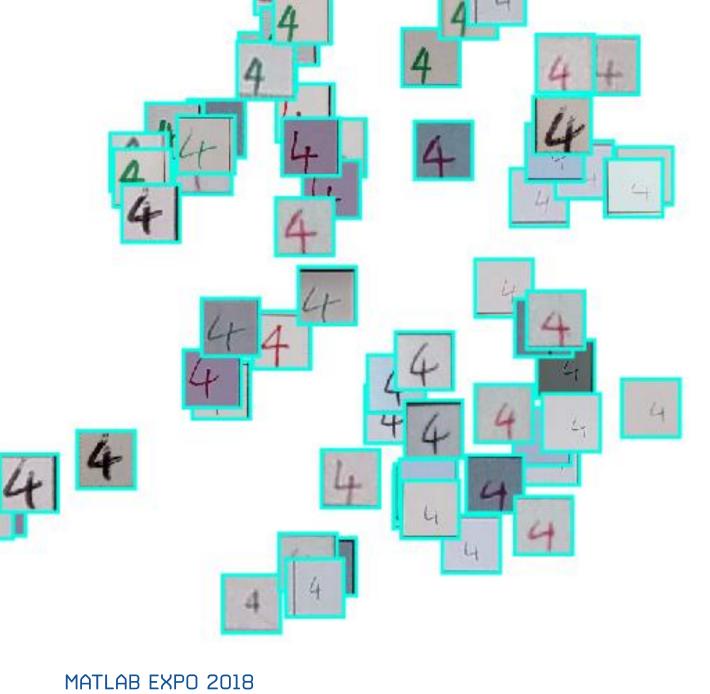


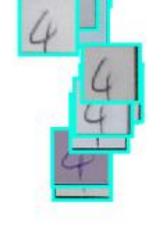
## activations()



# **Debugging a network with t-SNE**



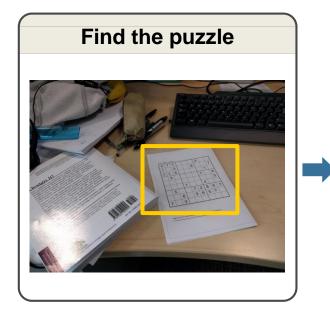




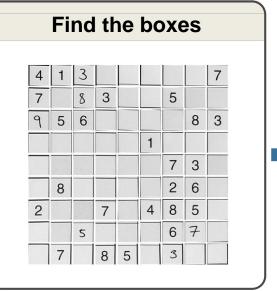


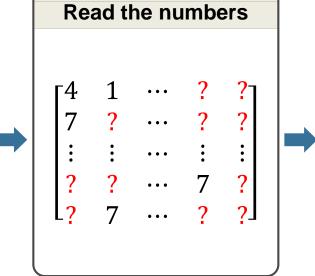


## An Example – Sudoku Solver



**Deep Learning** 





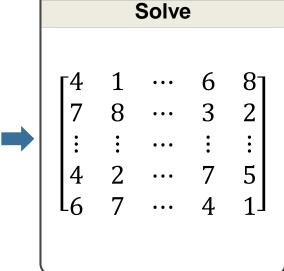
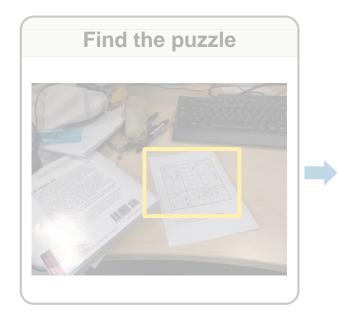


Image Processing

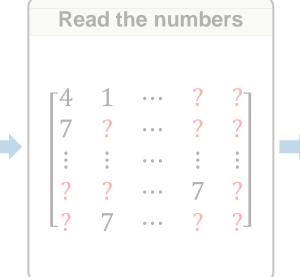
Deep Learning

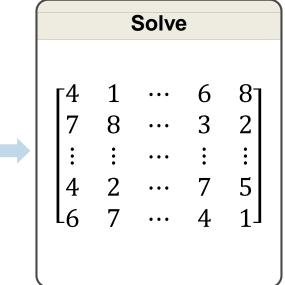


## Step 4 – Solve



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







## How can we solve a sudoku?

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## Solving Sudoku with MATLAB

#### By Cleve Moler, MathWorks

Human puzzle-solvers and computer programs use very different Sudoku-solving techniques. The fascination with solving Sudoku by hand derives from the discovery and mastery of a myriad of subtle combinations and patterns that provide hints about the final solution. It is not easy to program a computer to duplicate these human pattern-recognition capabilities. For the reason, most Sudoku-solving programs take a very different approach, relying on the computer's almost limitless capacity to carry out brute-force trial and error. That is the approach that I used for the MATLAB® program.

#### The Sudoku Challenge

As you probably know, solving a Sudoku involves filling in a 9-by-9 grid so that each row, column, and major 3-by-3 block contains all the digits 1 through 9. The initial grid is populated with a few digits, known as *clues*. In contrast to magic squares and other numeric puzzles, no arithmetic is involved; the elements in a Sudoku grid could just as well be letters of the alphat or any other symbols.

Figure 1 shows an initial grid. I especially like the symmetry in this example, which is due to Gordon Royle of the University c Western Australia. Figure 2 shows the solution.

	2			3			4	
6								3
		4				5		
			8		6			

#### MathWorks® Products Solutions Academia Support Community Events

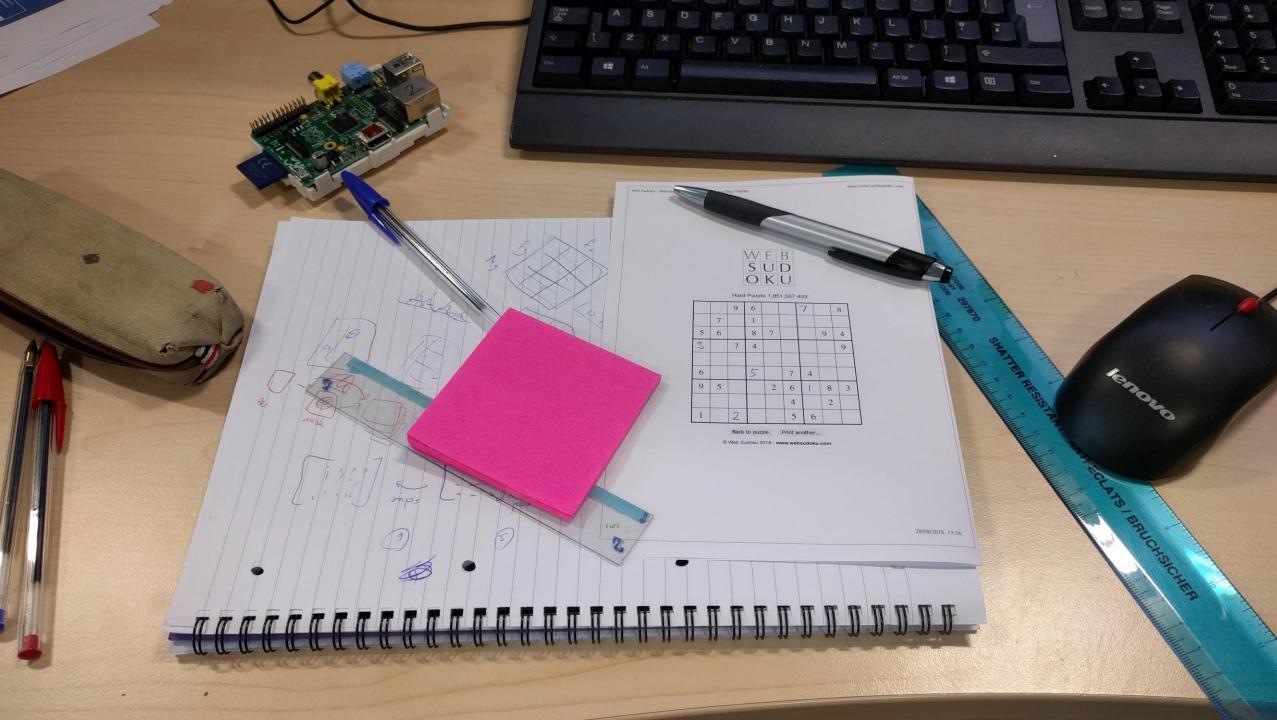
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Documentation	
CONTENTS Close	
< Examples Home	Solve Sudoku Puzzles Via Integer Programming: Problem-Based
< Optimization Toolbox 0 < Mixed-Integer Linear Programming	This example shows how to solve a Sudoku puzzle using binary integer programming. For the solver-based approach, see Solver you probably have seen Sudoku puzzles. A puzzle is to fill a 9-by-9 grid with integers from 1 through 9 so that each integer a
<ul> <li>Optimization Toolbox</li> <li>Linear Programming and Mixed- Integer Linear Programming</li> <li>Problem-Based Optimization</li> </ul>	partially populated with clues, and your task is to fill in the rest of the grid. Initial Puzzle Here is a data matrix B of clues. The first row, B(1,2,2), means row 1, column 2 has a clue 2. The second row, B(1,5,3), m
Solve Sudoku Puzzles Via Integer Programming: Problem-Based ON THIS PAGE Initial Puzzle Binary Integer Programming Approach Express the Rules for Sudoku as Constraints Express Clues Sudoku in Optimization Problem Form Function to Draw the Sudoku Puzzle	<pre>B = [1,2,2; 1,5,3; 1,8,4; 2,1,6; 2,9,3; 3,3,4; 3,7,5; 4,4,8; 4,6,6; 5,1,8; 5,5,1; 5,9,6; 6,4,7; 6,6,5; 7,3,7; 7,7,6; 8,1,4; 8,9,8; 9,2,3; 9,5,4; 9,8,2]; drawSudoku(B) % For the listing of this program, see the end of this example.</pre>

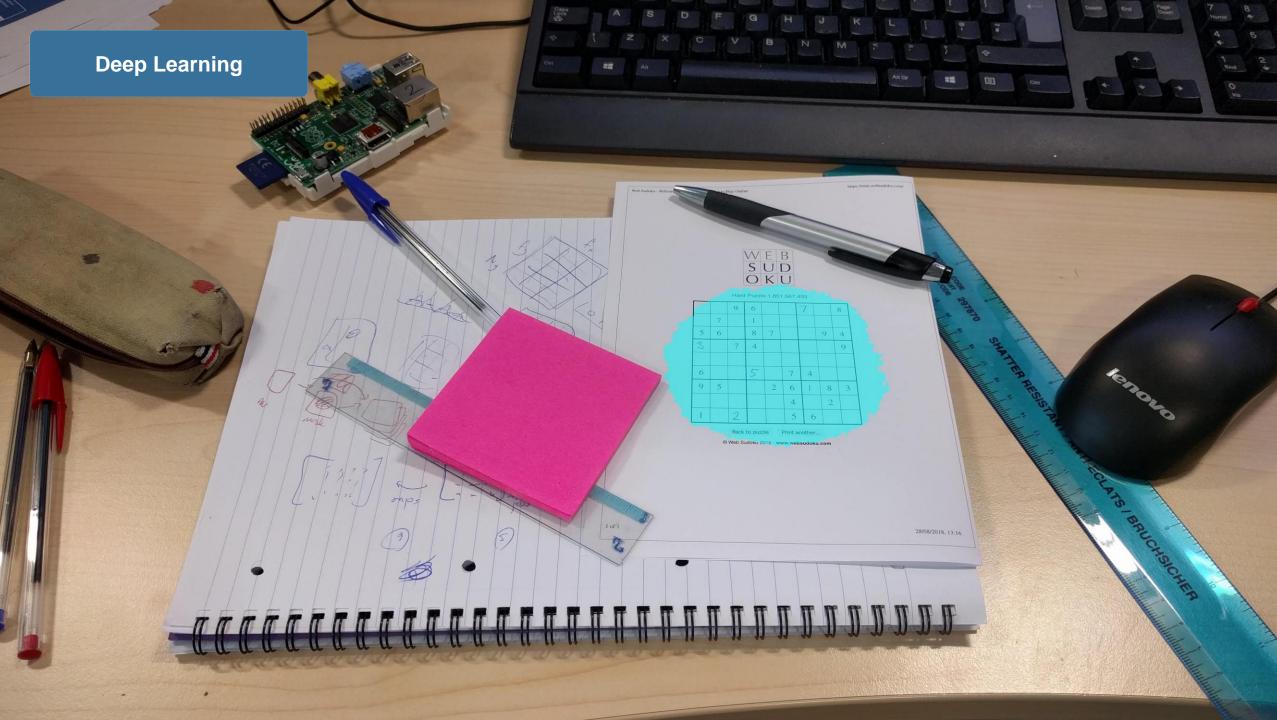
	2		3		4	
6						3
		4		5		



# Step 4 – Solve

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







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SHAT

28/08/2018, 13:16

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Cape Look

1 of 1

2

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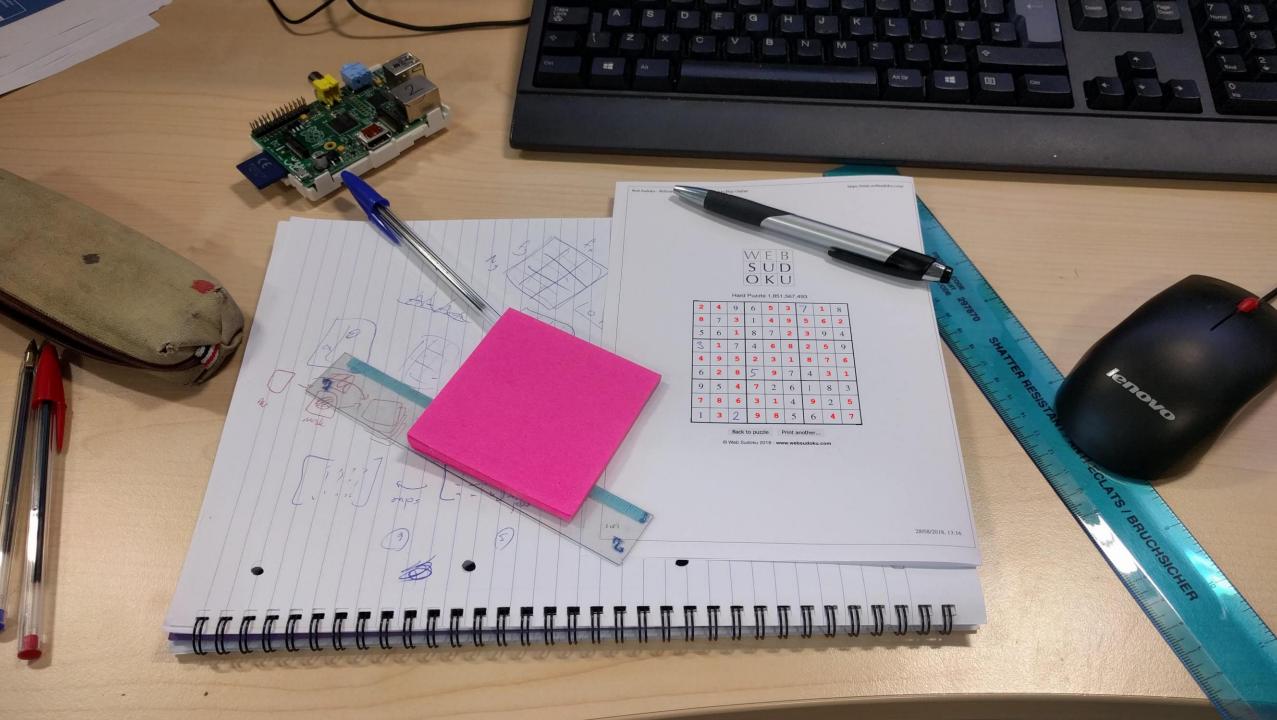
Back to puzzle Print another...

Deep Learning

arning			9	6			7	M	8	
		7		1						
	5	6		8	7			9	4	
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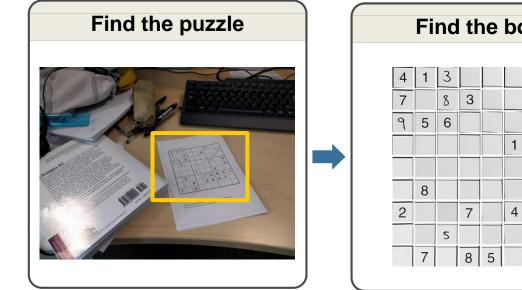
Optimisation

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8	
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8 1	
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7	F
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## An Example – Sudoku Solver



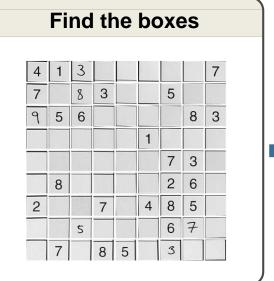
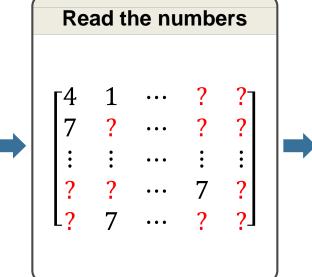
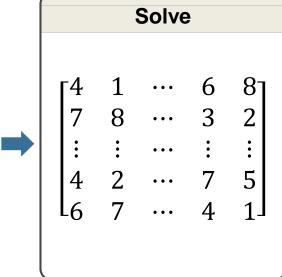


Image Processing





**Deep Learning** 

Optimisation

**Deep Learning** 



## Image Processing and Computer Vision with MATLAB

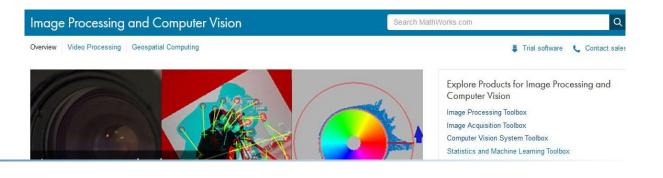
- Both deep learning and image processing are great tools for computer vision.
- Use the right combination of tools to get the job done.
- MATLAB makes it easy and efficient to do both image processing and deep learning together.
- MATLAB helps you integrate a computer vision algorithm into the rest of your workflow.



## Try out the example code (Search for: Deep Sudoku Solver)



Try what's new in Image Processing and Computer Vision toolboxes



Talk to us about your (computer vision) problems

