

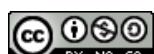
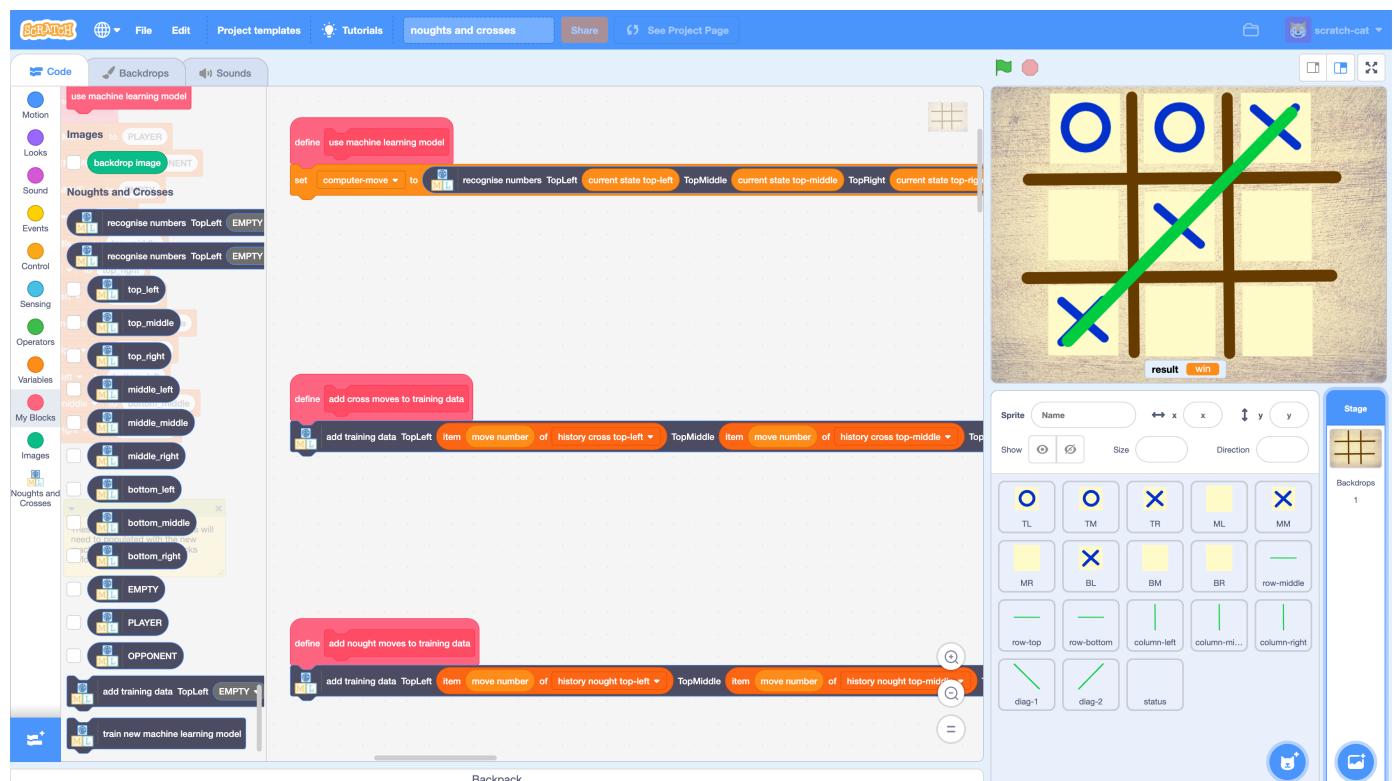


Noughts & Crosses

In this project you will create a noughts and crosses game in Scratch that is able to learn from how you play.

You won't give it instructions for how to play, or tell it what the objective or rules of the game are.

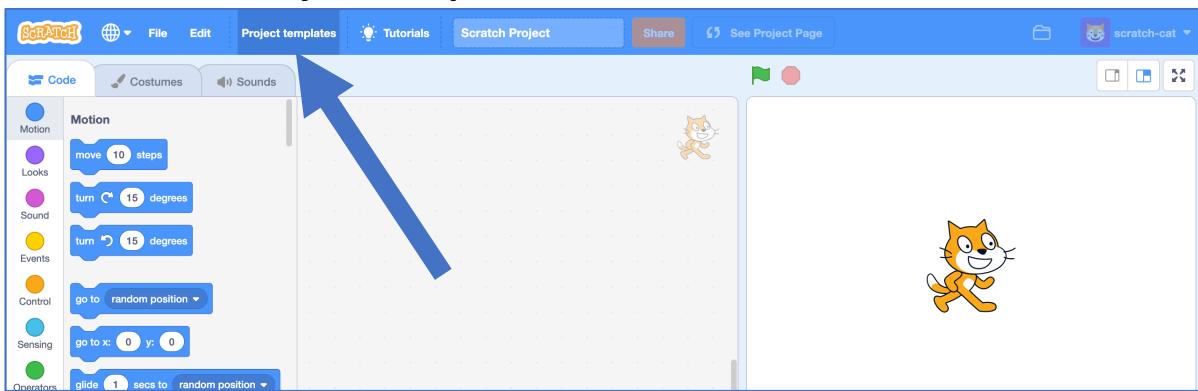
Instead, you'll show it examples of you playing the game. When it's seen enough examples to start trying to play for itself, you'll tell it when it beats you.



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1. Go to <https://scratch.machinelearningforkids.co.uk/> in a browser.

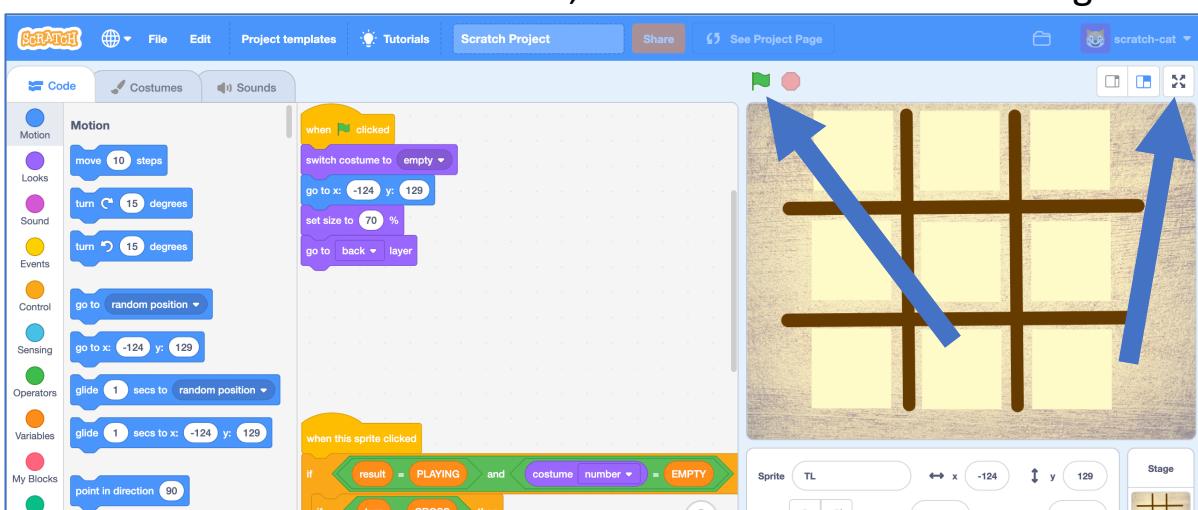
2. Click on Project templates



3. Click on the Noughts and Crosses project template

Click Project templates -> Noughts and Crosses

4. Click the full-screen button, and then click the Green Flag



5. Play a few games of noughts and crosses

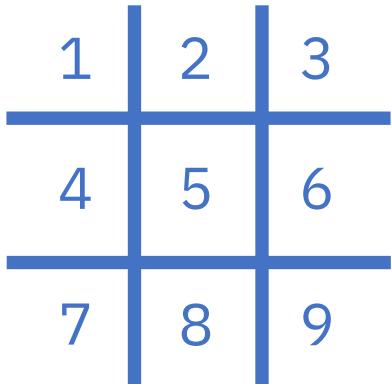
You are CROSS (X), the computer is playing as NOUGHTS (O).

Click the green flag to start a new game, then click on the game board.

6. Can you see how the computer is choosing where to put its moves?

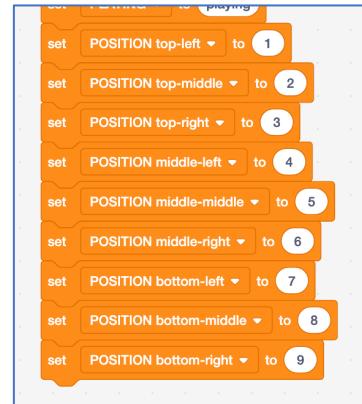
*When you've worked it out, look at the Computer move block in the Stage
Were you right?*

Representing noughts and crosses in Scratch



The positions of spaces on the noughts and crosses board are numbered from 1 to 9.

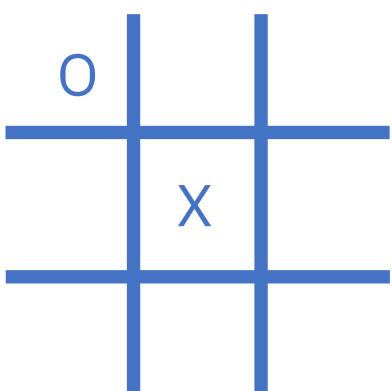
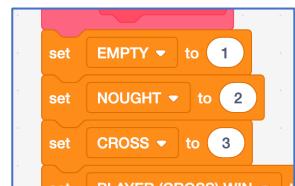
Data constants are used to make it easier to refer to them in scripts.



Empty = 1
O = 2
X = 3

An empty space is shown in costume 1.
A nought O is shown in costume 2.
A cross X is shown in costume 3.

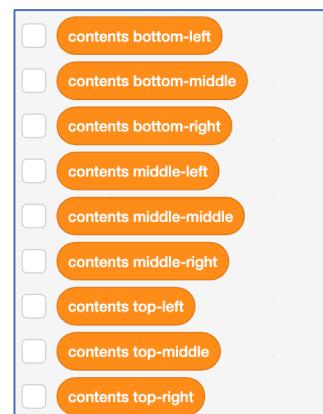
Data constants are used to make it easier to refer to these in scripts.



Variables are used to store the current state of the game.

For example, at this point:

contents top-left = 2
contents middle-middle = 3
contents bottom-right = 1



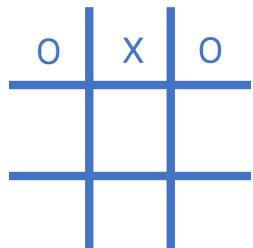
Each of the green row and column sprites check to see if someone has won.

This happens after every move.

What are you going to do?

You're going to train a computer to play noughts and crosses. You'll do this by showing it examples of how you play the game.

Imagine the board looks like this and it's X's turn.

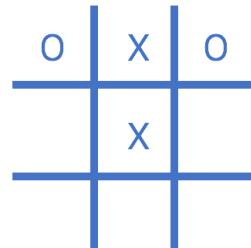


Imagine you decide to put your X in the centre space.

top-left	opponent
top-middle	player
top-right	opponent
middle-left	empty
middle-middle	empty
middle-right	empty
bottom-left	empty
bottom-middle	empty
bottom-right	empty

choice : middle-middle

Imagine the board looks like this and it's O's turn.



Imagine you decide to put your O in the bottom middle space.

top-left	player
top-middle	opponent
top-right	player
middle-left	empty
middle-middle	opponent
middle-right	empty
bottom-left	empty
bottom-middle	empty
bottom-right	empty

choice : bottom-middle

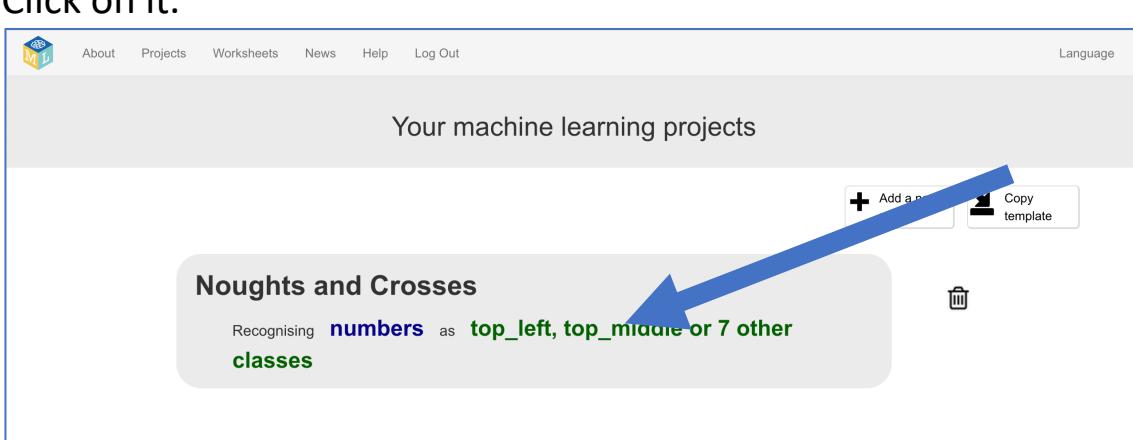
Using “opponent” and “player” instead of “nought” and “cross” means the computer can learn from both nought and cross moves.

You'll use examples of moves from the player that wins the game to train the computer.

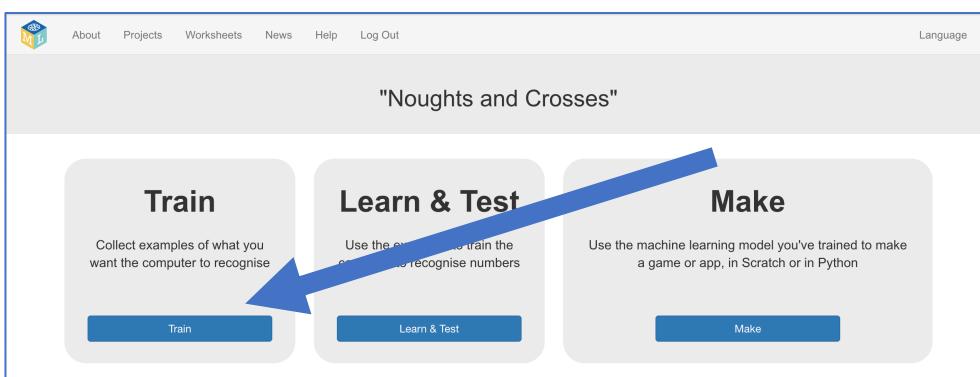
If you (X) win, you'll use your moves as examples to train the computer. If the computer (O) wins, you'll use the computer's moves to train with.

These **examples of moves that lead to winning** will teach the computer how to play to win!

- 7.** Close Scratch window then go to <https://machinelearningforkids.co.uk>
- 8.** Click on “**Get started**”
- 9.** Click on “**Log In**” and type in your username and password
*If you don't have a username, ask your teacher to create one for you.
If you can't remember your password, ask your teacher to reset it for you.*
- 10.** Click on “**Projects**” on the top menu bar
- 11.** Click on the “**Copy template**” button.
- 12.** Import the “**Noughts and Crosses**” project template.
- 13.** You should see “**Noughts and Crosses**” in your list of projects.
Click on it.



- 14.** Click the “**Train**” button



- 15.** The template project has training buckets to store examples of noughts and crosses game moves.

The screenshot shows a web-based machine learning project interface. At the top, there's a navigation bar with links for About, Projects, Worksheets, News, Help, Log Out, and Language. The main title is "Recognising numbers as top_left, top_middle or 7 other classes". Below the title, there's a link "< Back to project". On the right side, there's a button "+ Add new label". The interface is divided into a grid of nine boxes, each representing a class label: top_left, top_middle, top_right, middle_left, middle_middle, middle_right, bottom_left, bottom_middle, and bottom_right. Each box has a small "+ Add example" button at the bottom left. The labels are written in green text.

- 16.** Click the “< Back to project” link

- 17.** Click on the “Make” button

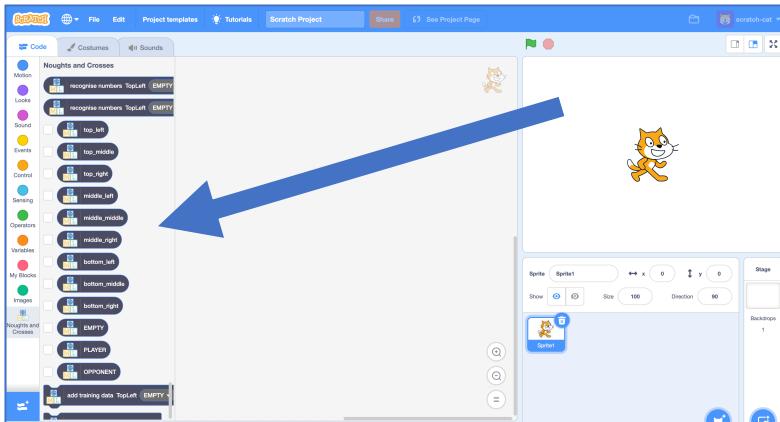
- 18.** Click on “Scratch 3”

- 19.** Click on “straight into Scratch”

The warning that you haven't trained a machine learning model yet is okay – you'll use Scratch to collect your training examples.

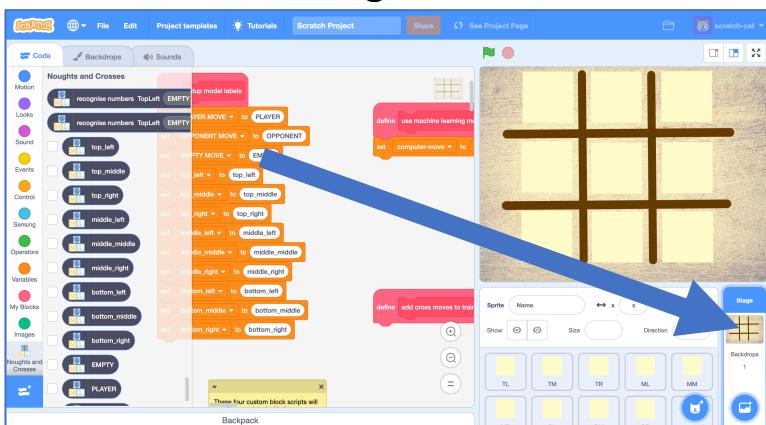
The screenshot shows the Scratch 3 interface. At the top, there's a navigation bar with links for About, Projects, Worksheets, News, Help, Log Out, and Language. The main title is "Using machine learning in Scratch 3". Below the title, there's a link "< Back to project". A blue arrow points from the text "Or you can go straight into Scratch" down towards the Scratch stage area. A message box says "You haven't trained a machine learning model yet." Another message box below it says "You can train one now and then come back to Scratch." and "Or you can go straight into Scratch". At the bottom, there are two boxes: one saying "Your project will add these blocks to Scratch." and another saying "It will look something like this - except with the name of your project." with a small image of a Scratch stage.

20. You should see blocks from your “noughts and crosses” project.

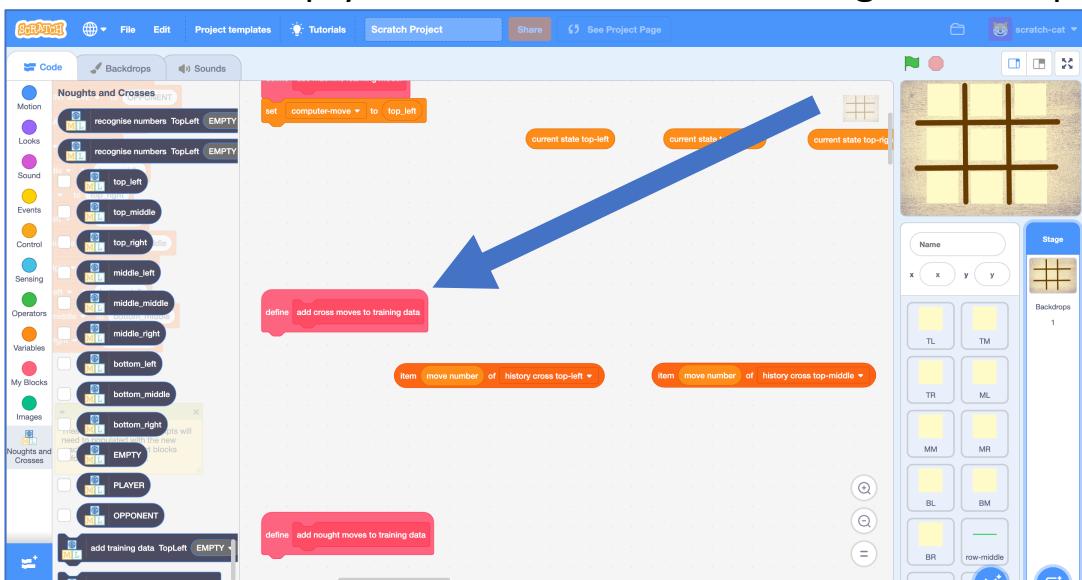


21. Open the Noughts and Crosses project template again.
Click on Project templates and then Noughts and Crosses

22. Click on the Stage



23. Find the empty “add cross moves to training data” script



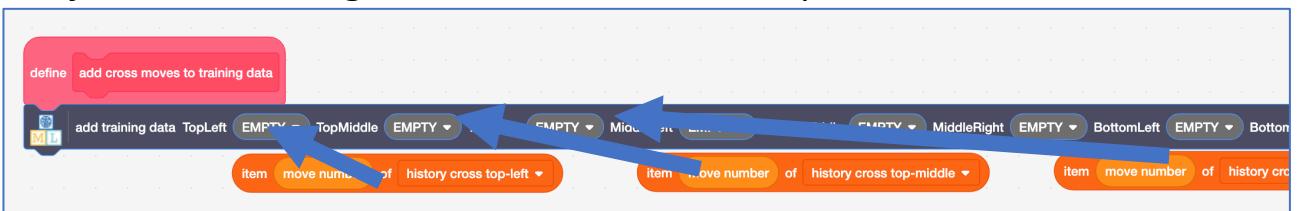
24. Add the “add training data” block



25. Copy the “item - move number” blocks into the spaces in the “add training data” block

The blocks are all ready for you underneath, and they are in the right order.

You just need to drag them into the “EMPTY” spaces



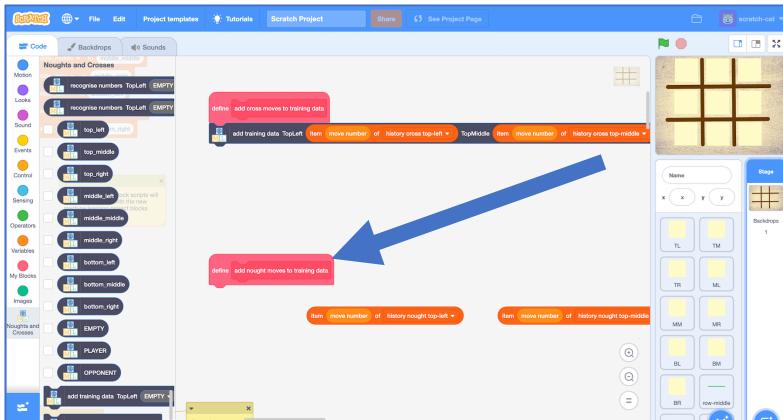
It should look like this when you’re finished. The names should match up: TopLeft goes with “history cross top-left”, TopMiddle goes with “history cross top-middle”, etc.

The last box has the “history cross choice” block.



This is a complicated step – so take your time and do it carefully!

26. Find the empty “add nought moves to training data” script



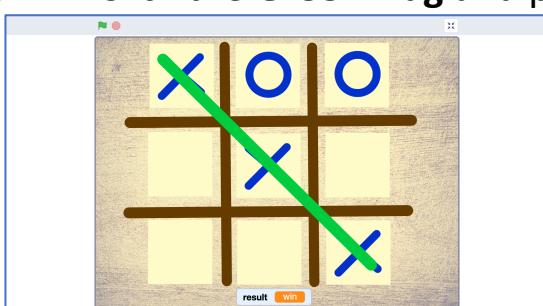
27. Add a “add training data” block and copy the move blocks into it in the same way as you did with the cross moves

*Make sure that names in each block match the label
e.g. TopLeft goes with “history nought top-left”.*



28. Click on “File”, then “Save to your computer” to save your project

29. Click the Green Flag and play one game against the computer



30. Go back to the training page

*Leaving the Scratch window open, go back to the training tool window.
Click the “< Back to project” link and then click “Train”*

The screenshot shows a web-based training interface for a game. At the top, there's a navigation bar with links for About, Projects, Worksheets, News, Help, Log Out, and Language. Below the navigation is a title bar that reads "Recognising numbers as top_left, top_middle or 7 other classes". A "Back to project" link is located in the top-left corner of the main content area. The main content consists of a 3x3 grid of boxes, each labeled with a position name: top_left, top_middle, top_right, middle_left, middle_middle, middle_right, bottom_left, bottom_middle, and bottom_right. Each box contains a "Add example" button. Some boxes also contain a small preview window showing board states:

- top_left**: Shows a list of board states: TopLeft EMPTY, TopMiddle EMPTY, TopRight EMPTY, MiddleLeft EMPTY, MiddleMiddle EMPTY, MiddleRight EMPTY, BottomLeft EMPTY, BottomMiddle EMPTY, BottomRight EMPTY.
- middle_middle**: Shows a list of board states: TopLeft PLAYER, TopMiddle OPPONENT, TopRight EMPTY, MiddleLeft EMPTY, MiddleMiddle EMPTY, MiddleRight EMPTY, BottomLeft EMPTY, BottomMiddle EMPTY, BottomRight EMPTY.
- bottom_right**: Shows a list of board states: TopLeft PLAYER, TopMiddle OPPONENT, TopRight OPPONENT, MiddleLeft EMPTY, MiddleMiddle PLAYER, MiddleRight EMPTY, BottomLeft EMPTY, BottomMiddle EMPTY, BottomRight EMPTY.

A green circle with the number "1" is drawn around the "middle_middle" box.

31. Look at your training so far

Each item is a move made by the winning player.

The details in each item describe the state of the board at the time the winning player made that move.

32. Go back to Scratch window

33. Play several more games – you want lots of training examples to teach the computer how to play the game

When you think you've got examples of lots of different types of games, go back to the training tool window

34. Click the “< Back to project” link.

Then click the “Learn & Test” button.

35. If there is a “Train new machine learning model” button you can go to step **40**. Otherwise, carry on to step **36**.

36. You don’t have enough examples to train the computer yet

For the computer to know when it is a good idea to choose any space on the board, you need at least 5 examples of where you chose that space and ended up winning.

This page shows you how many examples you have so far. Look to see which one(s) you need more examples for.

The screenshot shows a web-based application for machine learning. At the top, there's a navigation bar with links for 'About', 'Projects', 'Worksheets', 'News', 'Help', 'Log Out', and 'Language'. The main title is 'Machine learning models'. Below the title, there's a link '< Back to project'. The interface is divided into two main sections: 'What have you done?' and 'What's next?'. The 'What have you done?' section contains text about collecting examples for a computer to recognize numbers in specific positions. It lists the number of examples collected for each position: top_left (2), top_middle (0), top_right (3), middle_left (0), middle_middle (4), middle_right (1), bottom_left (2), bottom_middle (0), and bottom_right (3). The 'What's next?' section encourages users to keep going and provides instructions to go back to the 'Train' page to collect more examples for each label, noting that at least five examples of each are needed as an absolute minimum.

37. Leave the “Learn & Test” window open.

Go back to the **Scratch** window.

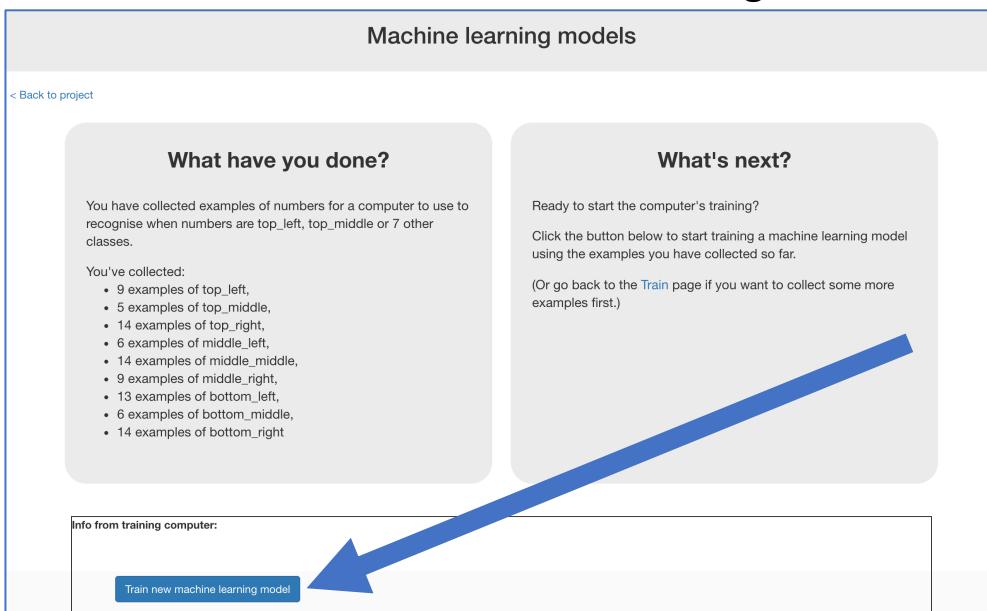
38. Play more games.

Try starting from a different position to get a variety of examples.

Try starting from positions that you know you need more examples of.

39. When you think you've got at least 5 examples of each space, go back to the “Learn & Test” window and **refresh** the page.
If there is still no “Train new machine learning model” button, you need to go back to step 33 and try again.

40. Click the “Train new machine learning model” button



What have you done so far?

You're teaching a computer to play noughts and crosses.

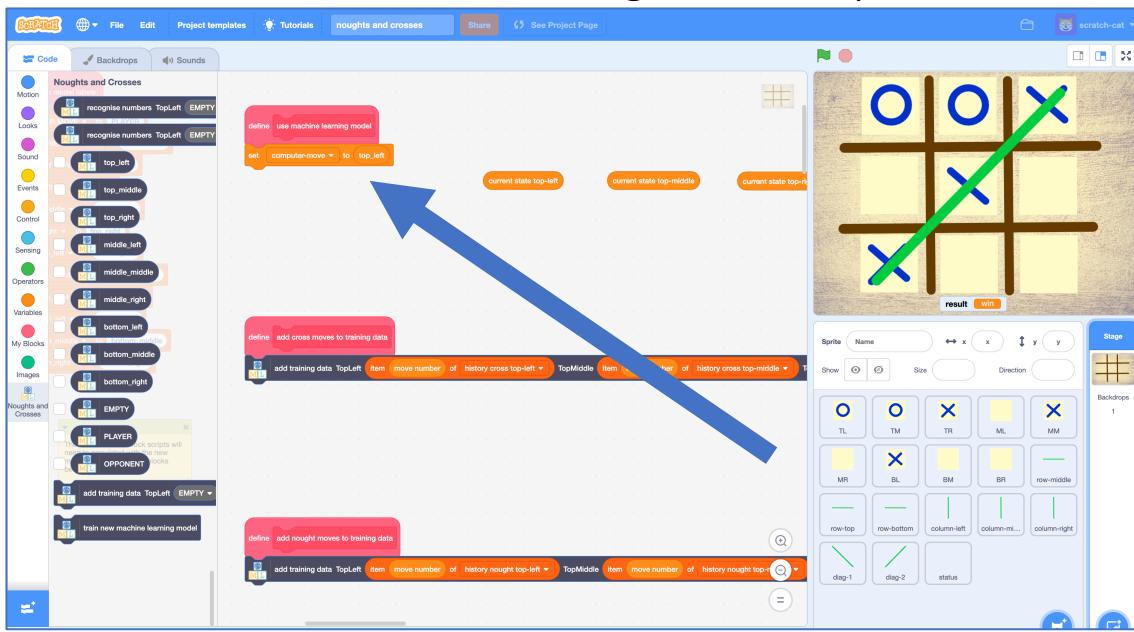
You've updated a Scratch noughts and crosses game so that it can collect examples of how you play and add them to a set of examples.

You've just used those examples to train a machine learning “model”.

The next step is to use that model to let the computer decide what move to make – instead of letting it just going for the next empty space every time.

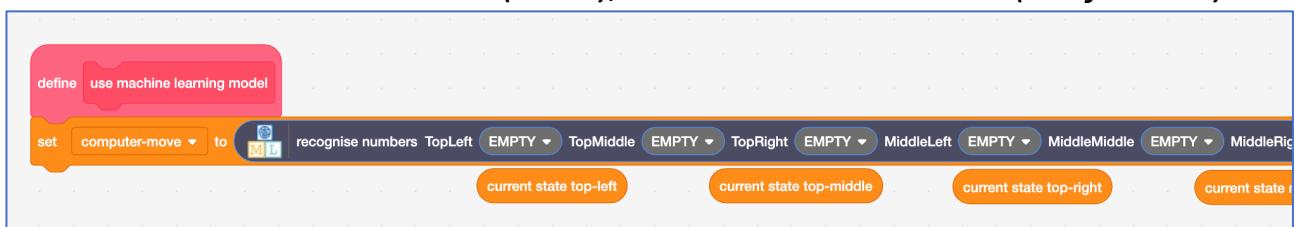
41. Go back to the Scratch window

42. Find the “use machine learning model” script



43. Replace the top_left block with “recognise numbers ... label”

Use the block that ends with (label), not the one that ends (confidence).



44. Copy the orange blocks underneath into the spaces in the “recognise numbers” block, similar to what you did before



45. Click on “File”, then “Save to your computer” to save your project

46. Play against the computer by clicking on the **Green Flag**
Avoid playing the same game over and over again. Choose different spaces to give the computer a variety of examples of how to play.

47. When it feels like you're playing the same games over and over, go back to the "Learn & Test" screen, and use the new training examples
*Click the "**Train a new machine learning model**" button again*

The screenshot shows the 'Machine learning models' screen in Scratch. At the top, there is a header bar with the title 'Machine learning models' and a 'Back to project' link. Below the header, there are two main sections:

- What have you done?**

You have trained a machine learning model to recognise when numbers are top_left, top_middle or 7 other classes.
You created the model on Friday, August 31, 2018 9:47 PM.
You have collected:
 - 34 examples of top_left,
 - 25 examples of top_middle,
 - 32 examples of top_right,
 - 25 examples of middle_left,
 - 55 examples of middle_middle,
 - 24 examples of middle_right,
- What's next?**

Try testing the machine learning model below. Enter an example of numbers below, that you didn't include in the examples you used to train it. It will tell you what it recognises it as, and how confident it is in that.
If the computer seems to have learned to recognise things correctly, then you can go to [Scratch](#) and use what the computer has learned to make a game!
If the computer is getting too many things wrong, you might want to go back to the [Train](#) page and collect some more examples. Once you've done that, click on the button below to train a new

48. Go back to the Scratch window and play more games
*When you're struggling to come up with new games, click "**Train new machine learning model**" button. Repeat until your model starts winning.*

What have you done?

You've trained a computer to play noughts and crosses.

You didn't have to describe the rules to the computer.

You didn't tell it that it should try to get three noughts in a row.

You didn't describe the difference between rows, columns or diagonals.

Instead, you showed it how you play, by collecting examples of decisions that you made when you win.

When it makes decisions that leads to it winning, this is added to its training data, so it can be even more confident in that approach in future.

This is called "reinforcement learning" because when it does something good you are "reinforcing" this by rewarding it.

Tips

Don't be kind!

You might be tempted to go easy on the computer when you're playing against it, particularly when it's just starting to learn and is playing very badly.

For example, you might have two crosses-in-a-row next to a blank space and could win. But instead, you might feel sorry for it doing badly and put a cross somewhere else instead to give it a chance.

Don't.

It is learning from the way that you play. If you don't complete a three-in-a-row when you can, you will be teaching it that it should do that.

If you want it to get better quickly, **play as well as you can**.

Mix things up with your examples

Try to come up with lots of different types of examples.

For example, start from a different position on the board on every turn.

Did you know?

People have been learning about machine learning by training a computer to play noughts and crosses for decades!

One famous example was **Donald Michie** – a British artificial intelligence researcher. During World War II, Michie worked at Bletchley Park as a code breaker.

In 1960, he developed “**MENACE**” – the Machine Educable Noughts And Crosses Engine. This was one of the first programs able to learn how to play noughts and crosses perfectly.

As he didn’t have a computer he could use, Michie built MENACE using 304 matchboxes and coloured glass beads.

Each matchbox represented a possible state of the board – like the examples that you’ve been collecting in your training data.

He put beads in the matchboxes to show how often a choice led to a win – the number of beads in the matchbox was like the number of times an example shows up in one of the buckets you created for your training data.

