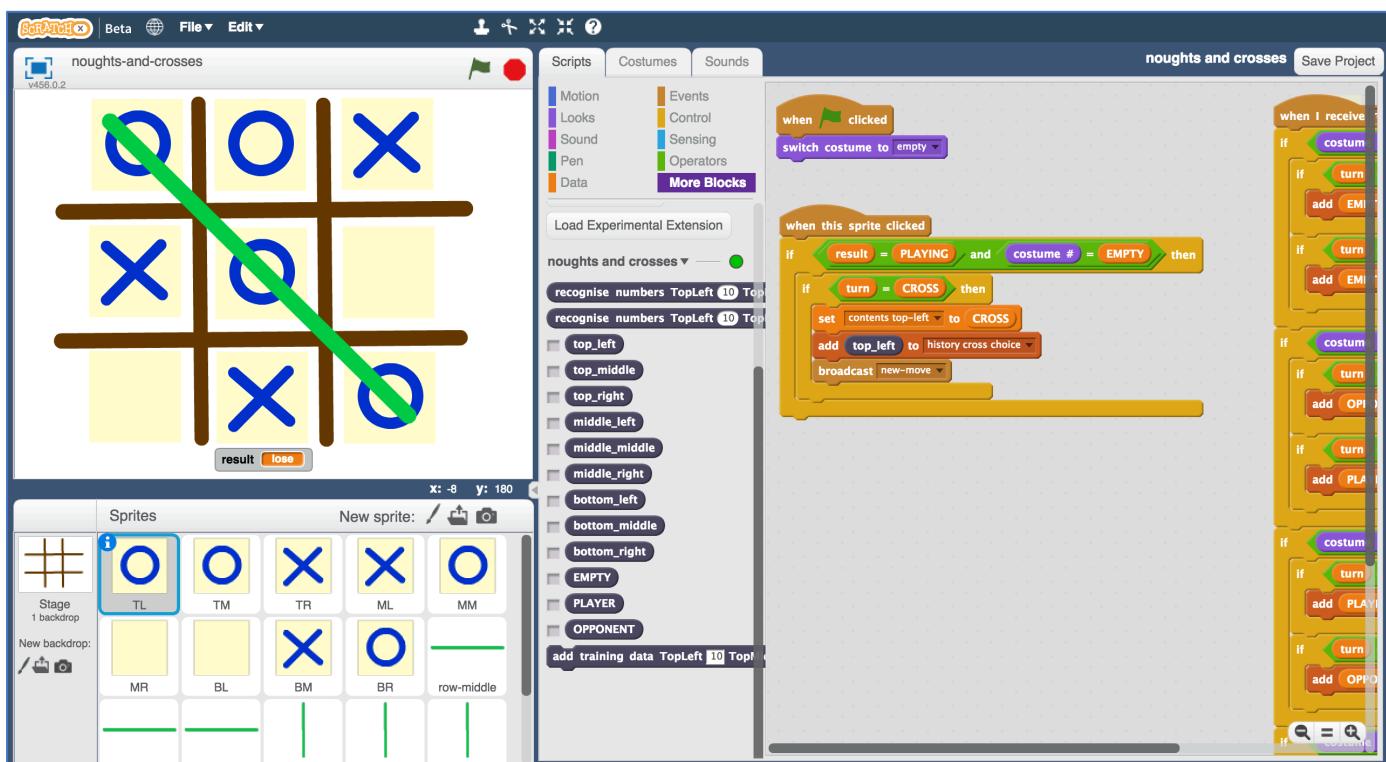


# Noughts & Crosses

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.



This project worksheet is licensed under a Creative Commons Attribution Non-Commercial Share-Alike License  
<http://creativecommons.org/licenses/by-nc-sa/4.0/>

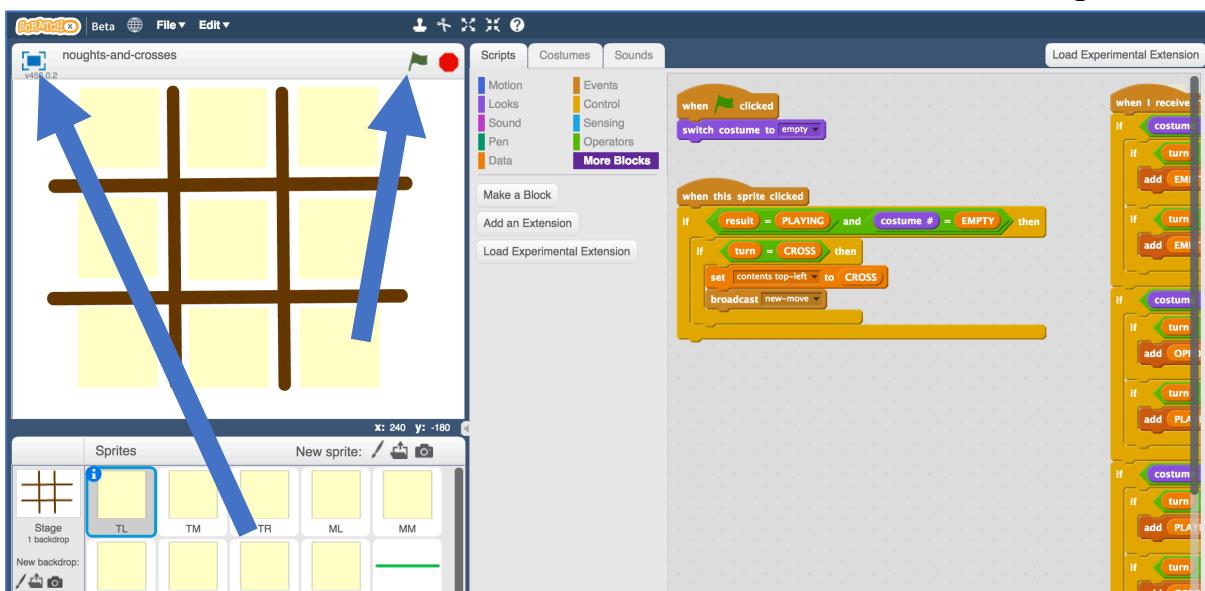
1. Go to <https://machinelearningforkids.co.uk/scratchx> in a browser.

2. Open the **noughts-and-crosses.sbx** starter file for this project.

*Click **File** -> **Load Project***

*If you haven't got this file, ask your teacher or group leader.*

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



4. Play a few games of noughts and crosses

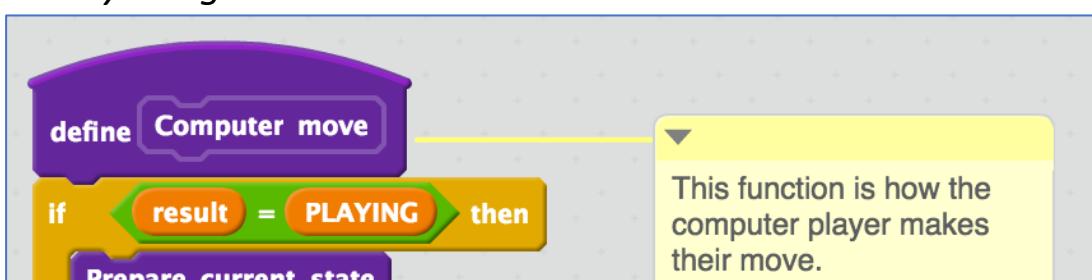
*You are CROSS (X), the computer is playing as NOUGHTS (O).*

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

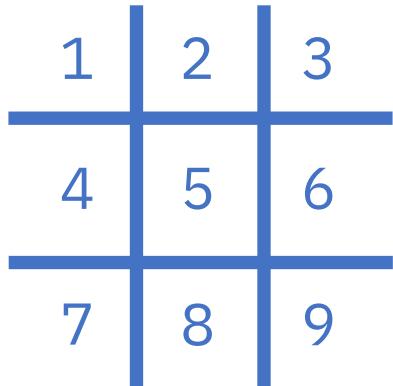
5. Can you see how the computer is choosing where to put its moves?

*When you think you've worked out the computer's strategy, look at the **Computer move** block in the **Stage***

*Were you right?*

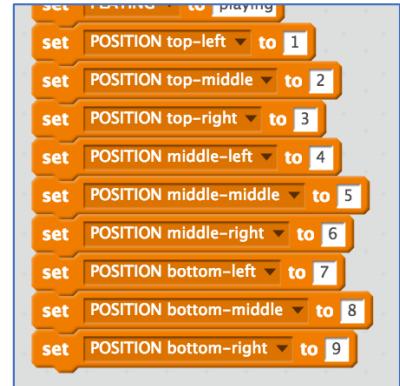


# Representing noughts and crosses in Scratch



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

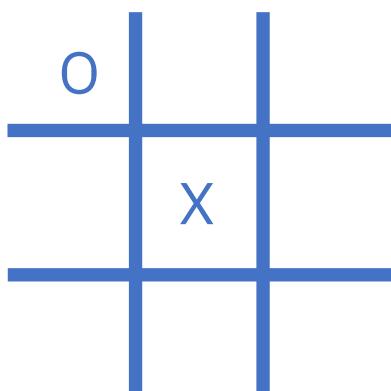
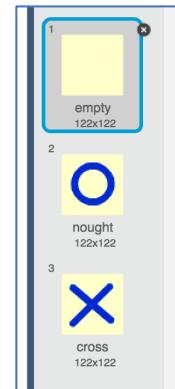
Data constants are used to make it easier to refer to them in scripts.



Empty = 1  
O = 2  
X = 3

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

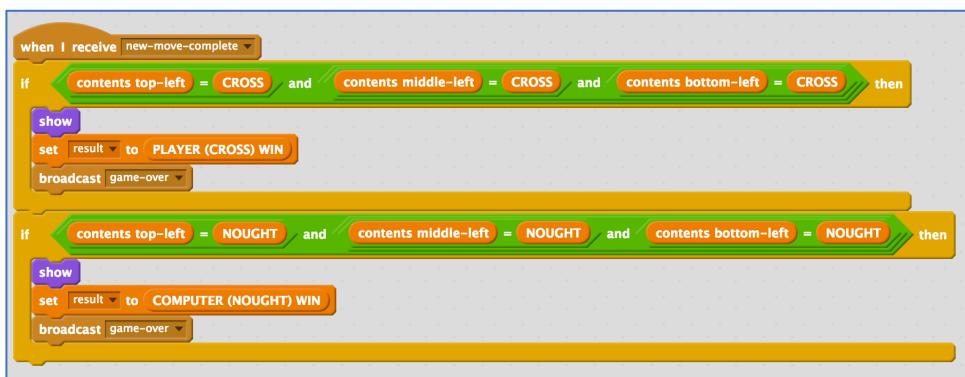
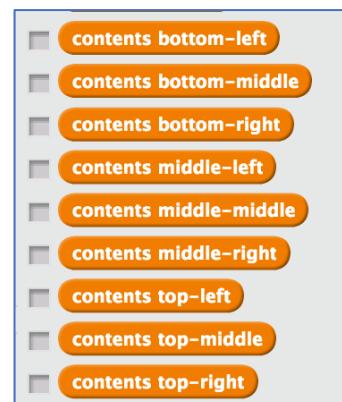
Data constants are used to make it easier to refer to these in scripts.



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



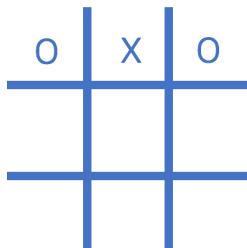
Each of the green row and column sprites check to see if someone has won.

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.

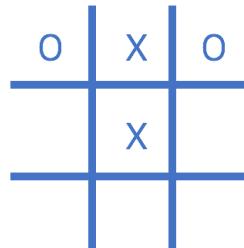


Imagine you decide to put your X in the centre space.

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

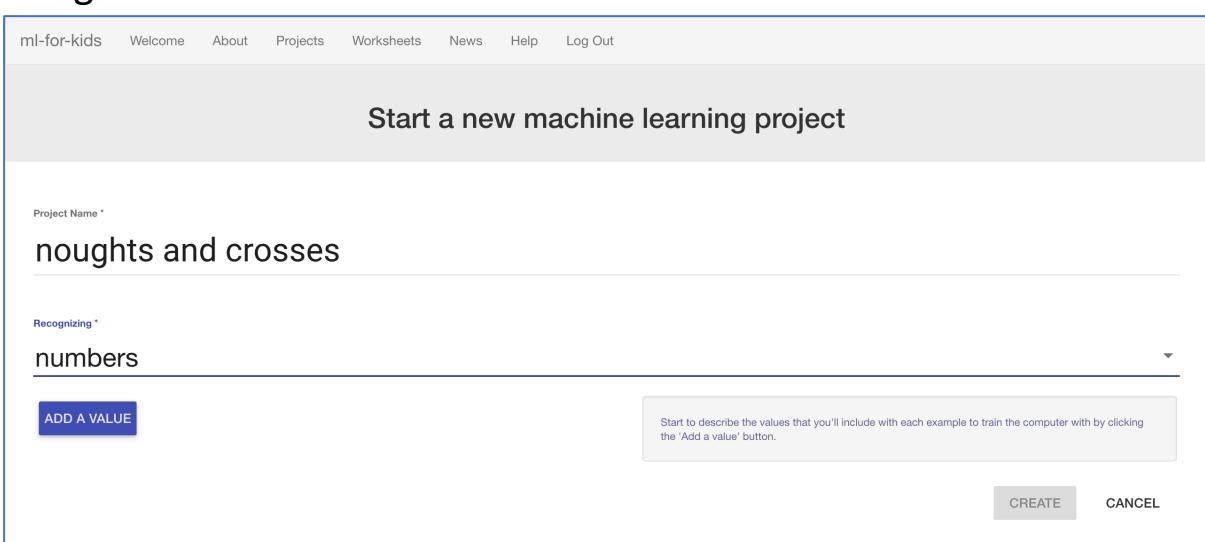
Using “opponent” and “player” instead of “nought” and “cross” means the computer can learn from both nought and cross moves.

You'll only use examples of moves from the player that wins the game.

If you (X) win, use your moves as examples to train the computer.  
If the computer (O) wins, 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!

- 6.** Close the Scratch window.
- 7.** Go to <https://machinelearningforkids.co.uk/> in a web browser
- 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 or group leader to create one for you.*  
*If you can't remember your username or password, ask your teacher or group leader to reset it for you.*
- 10.** Click on “**Projects**” on the top menu bar
- 11.** Click on the “**+ Add a new project**” button.
- 12.** Name your project “noughts and crosses” and set it to learn how to recognise “**numbers**”



The screenshot shows a web page titled "Start a new machine learning project". At the top, there is a navigation bar with links: ml-for-kids, Welcome, About, Projects, Worksheets, News, Help, and Log Out. Below the title, there are two input fields: "Project Name \*" containing "noughts and crosses" and "Recognizing \*" containing "numbers". A blue "ADD A VALUE" button is located below the "Recognizing" field. To the right of the "Recognizing" field is a tooltip box with the text: "Start to describe the values that you'll include with each example to train the computer with by clicking the 'Add a value' button." At the bottom right of the form are "CREATE" and "CANCEL" buttons.

- 13.** Click “**Add a value**” and name a value “TopLeft” and make it “multiple choice”.

Value 1 \*

TopLeft

Type of value \*

multiple-choice

Choices:

[add a choice](#)

If TopLeft can be described as numbers, choose "number".

If it can be described as choosing from a few options, choose "multiple-choice".

[ADD ANOTHER VALUE](#)

- 14.** Type “EMPTY” into the “**add a choice**” box and press Enter  
Type “PLAYER” into the “**add a choice**” box and press Enter  
Type “OPPONENT” into the “**add a choice**” box and press Enter  
*These are the possible contents for the top-left box in the noughts and crosses board. It can be empty, or it can have the player’s own shape (e.g. cross) in it, or it can have the opponent’s shape in it (e.g. cross).*

Value 1 \*

TopLeft

Type of value \*

multiple-choice

Choices:

[EMPTY](#) [PLAYER](#)

[OPPONENT](#)

[add a choice](#)

Type in another choice to use in your multiple-choice list, then press Enter.

[ADD ANOTHER VALUE](#)

- 15.** Click “Add another value” again and repeat to add values for the other eight positions on the board  
*Each example is the state of the board before a move that led to a win. TopMiddle, TopRight, MiddleLeft, MiddleMiddle, MiddleRight, BottomLeft, BottomMiddle, BottomRight*

*It's very important that you spell "EMPTY", "PLAYER" and "OPPONENT" in the same way for all nine positions.*

Project name: noughts and crosses

Recognizing: numbers

Value 1 * TopLeft multiple-choice Choices: EMPTY PLAYER OPPONENT	Value 2 * TopMiddle multiple-choice Choices: EMPTY PLAYER OPPONENT	Value 3 * TopRight multiple-choice Choices: EMPTY PLAYER OPPONENT
Value 4 * MiddleLeft multiple-choice Choices: EMPTY PLAYER OPPONENT	Value 5 * MiddleMiddle multiple-choice Choices: EMPTY PLAYER OPPONENT	Value 6 * MiddleRight multiple-choice Choices: EMPTY PLAYER OPPONENT
Value 7 * BottomLeft multiple-choice Choices: EMPTY PLAYER OPPONENT	Value 8 * BottomMiddle multiple-choice Choices: EMPTY PLAYER OPPONENT	Value 9 * BottomRight multiple-choice Choices: EMPTY PLAYER OPPONENT

**ADD ANOTHER VALUE**

**CREATE**   **CANCEL**

**16.** Click **Create**. You should see “noughts and crosses” show up in the list of your projects. Click on it.

Your machine learning projects

+ Add a new project

<b>newspapers</b> Recognising text as Daily_Express, Daily_Mirror or 2 other classes	<b>noughts and crosses</b> Recognising numbers
---	---

**17.** Click the “Train” button

ml-for-kids   Welcome   About   Projects   Worksheets   News   Help   Log Out

"noughts and crosses"

<b>Train</b> Collect examples of what you want the computer to recognise. <b>Train</b>	<b>Learn &amp; Test</b> Use the examples to train the computer to recognise numbers. <b>Learn &amp; Test</b>	<b>Scratch</b> Use the machine learning model you've trained to make a game in Scratch. <b>Scratch</b>
--	--	--

## 18. Click “+ Add new label” and create a label called “top left”

*Examples of making a move in the top-left box (in games that eventually ends in a win) will go in this bucket.*

The screenshot shows a web interface for a machine learning project. At the top, there is a navigation bar with links: ml-for-kids, Welcome, About, Projects, Worksheets, News, Help, and Log Out. Below the navigation bar, the title "Recognising numbers as top\_left" is displayed. A "Back to project" link is located above a large rectangular input field. To the right of the input field is a button labeled "+ Add new label". At the bottom of the input field is a "+ Add example" button.

## 19. Click “+ Add new label” again and create labels for the other eight spaces on the board.

“top middle”, “top right”, “middle left”, “middle middle”, “middle right”, “bottom left”, “bottom middle”, “bottom right”

The screenshot shows a 3x3 grid of rectangular input fields, each labeled with a specific position: top\_left, top\_middle, top\_right, middle\_left, middle\_middle, middle\_right, bottom\_left, bottom\_middle, and bottom\_right. Each input field has a "+ Add example" button at the bottom. In the top row, the first field is labeled "top\_left", the second "top\_middle", and the third "top\_right". In the middle row, the first field is labeled "middle\_left", the second "middle\_middle", and the third "middle\_right". In the bottom row, the first field is labeled "bottom\_left", the second "bottom\_middle", and the third "bottom\_right". A "Back to project" link is visible above the grid. A button labeled "+ Add new label" is located in the top right corner of the page.

## 20. Click the “< Back to project” link then click **Scratch**

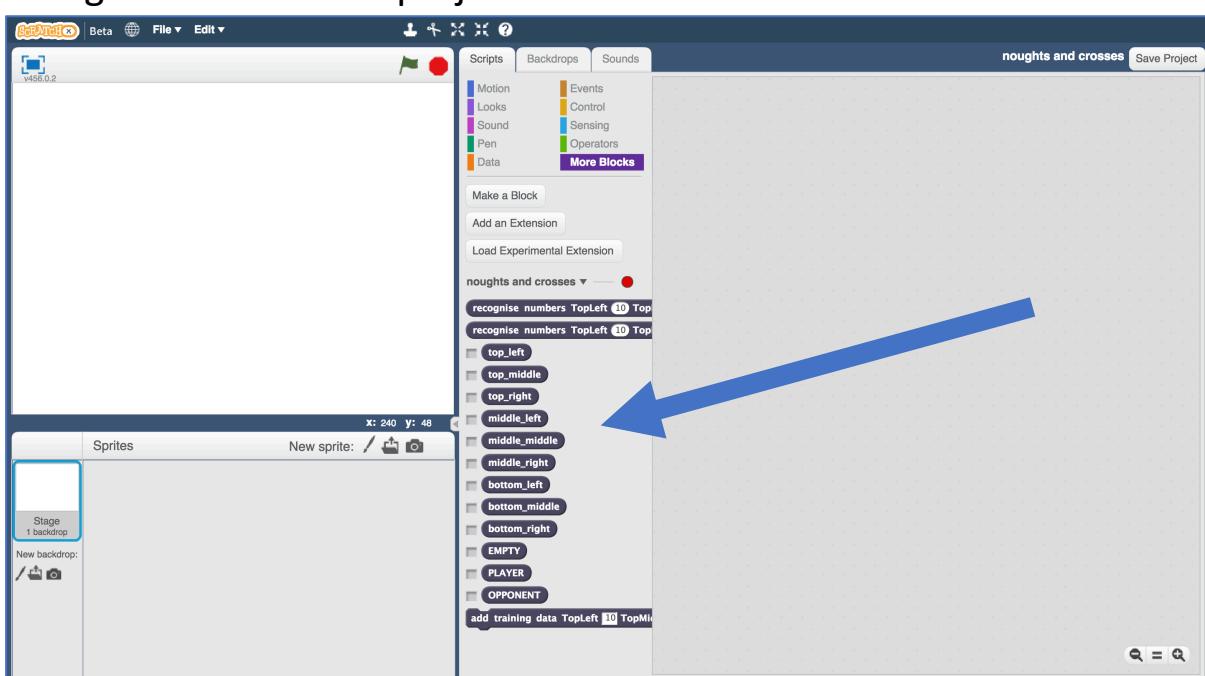
## 21. Click the **Open in Scratch** button

*It will warn you that you haven't trained the computer yet – but that's okay, as you'll use Scratch to collect the training examples.*

*Click the “go straight into Scratch now” link.*

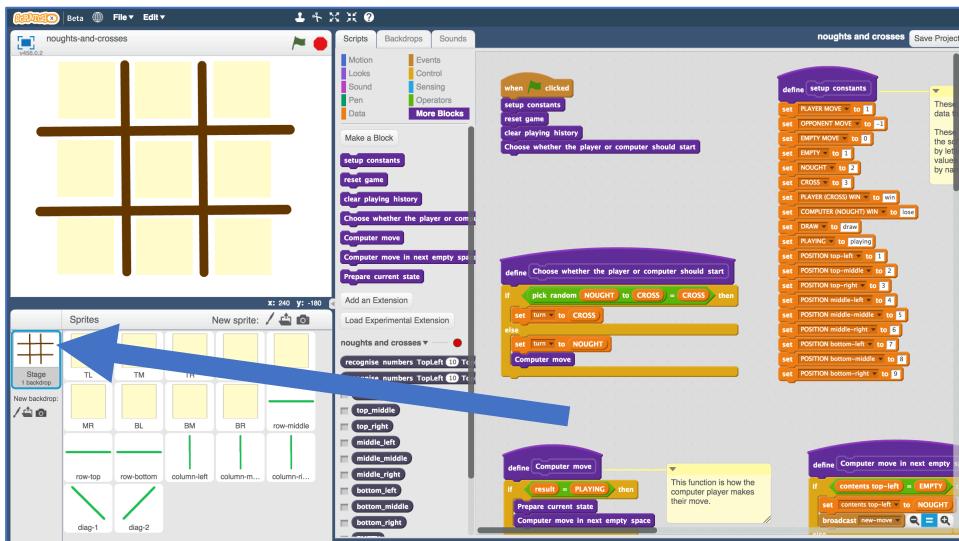
The screenshot shows the 'More Blocks' tab in the Scratch project interface. It displays two sections: one for 'recognise numbers' and another for 'recognise text'. The 'recognise numbers' section shows various blocks for identifying positions like 'TopLeft', 'TopMiddle', etc., with a note that it returns a confidence level from 0-100. The 'recognise text' section shows blocks for 'confidence' and 'label'. A Scratch script example is shown: 'if [recognise numbers TopLeft v10] then [say [I think that was top\_left v]]'. To the right, a Scratch stage view shows a green cat sprite with a script attached. A legend explains the colored circles: green means trained, yellow means training, and red means error. A 'Back to project' link is at the top left, and an 'Open in Scratch' button is at the bottom left.

## 22. You should see new blocks in the “More blocks” section from your “noughts and crosses” project.



**23.** Open the “noughts-and-crosses.sbx” starter project file again.  
**Click *File* -> *Load Project***

**24.** Click on the “Stage”



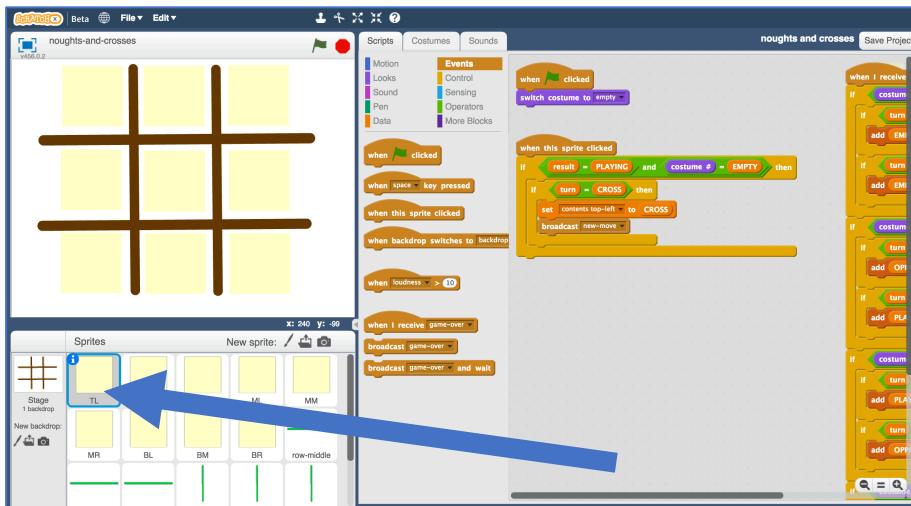
**25.** Modify the custom block “**setup constants**” to use the multiple choice values you created

*Drag the “EMPTY”, “PLAYER” and “OPPONENT” blocks from your “noughts and crosses” project into the top three spaces in the script like in the picture below.*



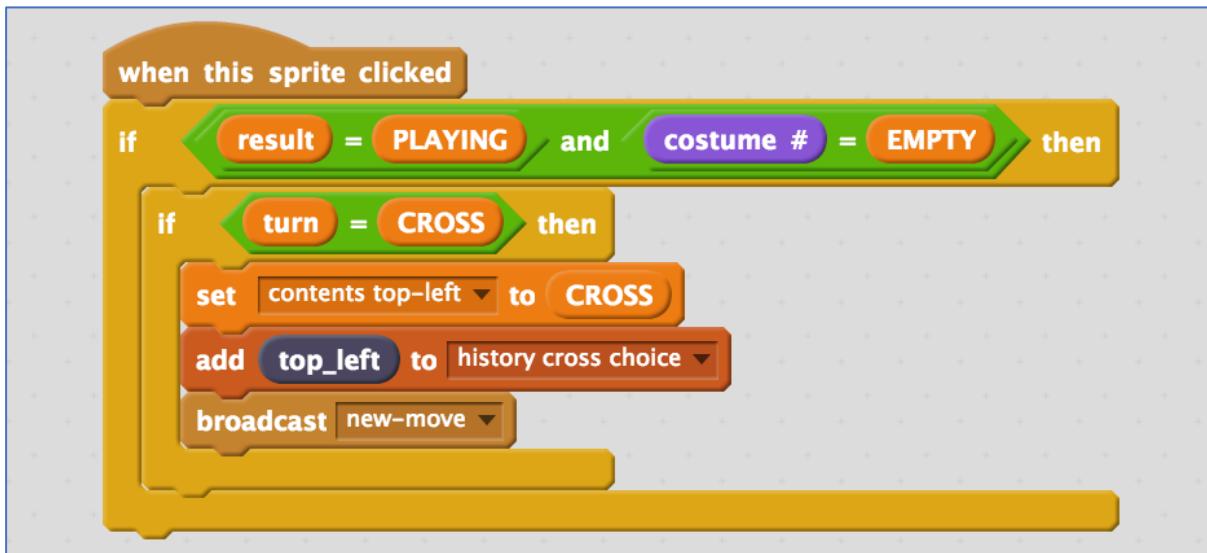
## 26. Click the TL (top-left space) sprite

You'll update the script to store when you click on this space for your move.



## 27. Modify the “When this sprite clicked” script to add `top_left` to the history of cross choices.

You just need to add a single block to get the script to look like this:



## 28. Click the TM (top-middle) sprite.

Modify the script to add **top\_middle** to the history of cross choices.



## 29. Repeat for the other seven board sprites

Add *top\_right* to the *TR* sprite. Add *middle\_left* to the *ML* sprite.

Add *middle\_middle* to the *MM* sprite. Add *middle\_right* to the *MR* sprite.

Add *bottom\_left* to the *BL* sprite. Add *bottom\_middle* to the *BM* sprite.

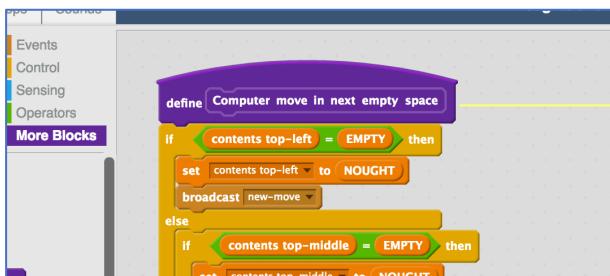
Add *bottom\_right* to the *BR* sprite.



**30.** Click on the “Stage” again

*You'll update the script to store when the computer makes its move*

**31.** Find the “Computer move in next empty space” script



**32.** Modify the script to add each of the computer's moves to the history of nought choices.

*You only need to add the add CHOICE to 'history nought choice' blocks*



```

broadcast new-move ▾
else
if contents middle-left = EMPTY then
set contents middle-left ▾ to NOUGHT
add middle_left to history nought choice ▾
broadcast new-move ▾
else
if contents middle-middle = EMPTY then
set contents middle-middle ▾ to NOUGHT
add middle_middle to history nought choice ▾
broadcast new-move ▾
else
if contents middle-right = EMPTY then
set contents middle-right ▾ to NOUGHT
add middle_right to history nought choice ▾
broadcast new-move ▾
else
if contents bottom-left = EMPTY then
set contents bottom-left ▾ to NOUGHT
add bottom_left to history nought choice ▾
broadcast new-move ▾
else
if contents bottom-middle = EMPTY then
set contents bottom-middle ▾ to NOUGHT
add bottom_middle to history nought choice ▾
broadcast new-move ▾
else
if contents bottom-right = EMPTY then
set contents bottom-right ▾ to NOUGHT
add bottom_right to history nought choice ▾
broadcast new-move ▾
else
set result ▾ to DRAW
broadcast game-over ▾

```

The script handles all possible moves for the 'Nought' player. It checks each of the four positions (middle-left, middle-middle, middle-right, bottom-left, bottom-middle, bottom-right) in turn. If a position is empty, it sets it to 'NOUGHT', adds it to the 'history nought choice' list, and broadcasts a 'new-move'. If none of the positions are empty, it sets the 'result' to 'DRAW' and broadcasts 'game-over'.

### 33. Create the following script (still in the Stage)

*This will add all of the history of moves made by the winning player to the training data that you will use to train the computer.*



### 34. Add the following items to the first “add training data” block

*If the game ends with the player (CROSS) winning, all the moves you want to add to the training data should be from the cross histories.  
And you end with the choice of move that was made.*

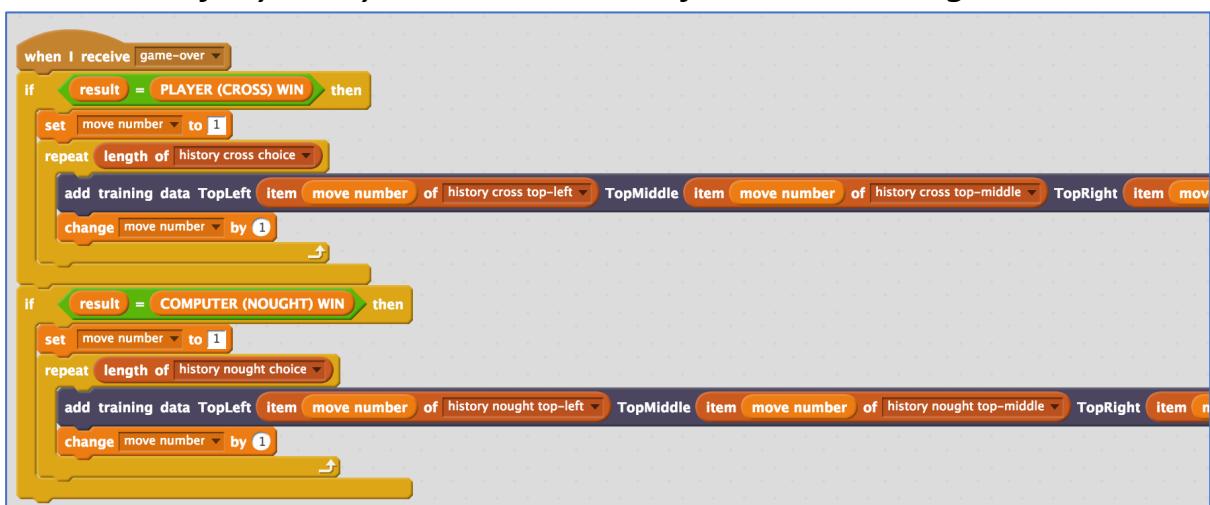


**35.** Add the following items to the **second** “add training data” block  
*If the game ends with the computer (NOUGHT) winning, all the moves you want to add to the training data should be from the **nought** histories. And you end with the choice of move that was made.*



**36.** The final script should look like this

*Double-check that the top “add training data” row is all from “history nought” lists, and matches the board space. (e.g. TopLeft with top-left)  
 Double-check that the bottom “add training data” row is all from “history cross” lists, and matches the board space. (e.g. TopLeft with top-left)  
 Do this carefully – any mistakes will confuse the training.*



**37.** Save your project  
*Click **File -> Save Project***

## 38. Play a few games

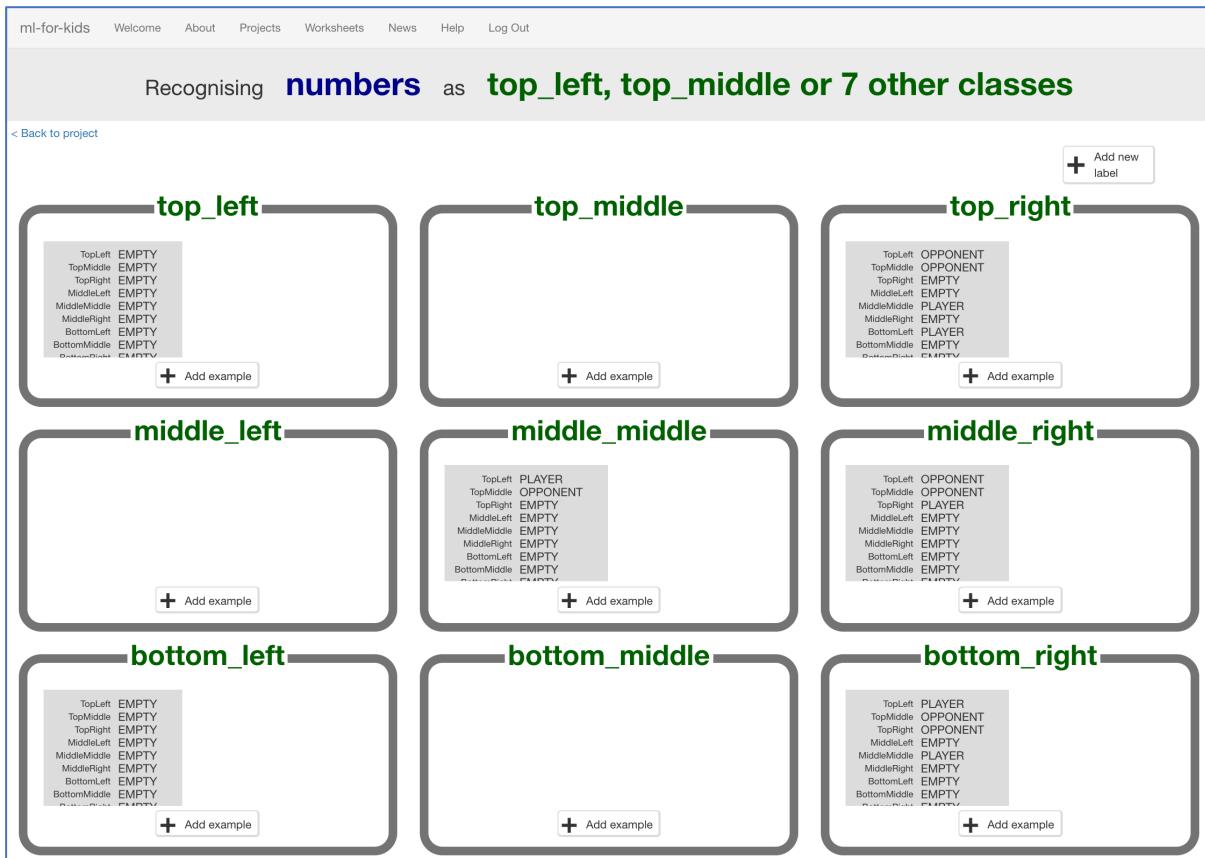
*Click on the **Green Flag** as you did before.*

*It is better to play in full-screen mode to avoid accidentally moving sprites.*

## 39. 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**”*



## 40. Look at your training so far

*Each item is the state of the board at the time you or the computer made a move (in a game that you or the computer won).*

*The bucket that the item is in is the move that you made.*

*If there are any empty buckets – like **top\_middle**, **middle\_left** and **bottom\_middle** in the screenshot before – that means you haven’t made a move in that space in a game that you won yet.*

- 41.** Click the “< Back to project” link. Click the “Learn & Test” button.
- 42.** If there is a “Train new machine learning model” button you can go to step **47**. Otherwise, carry on to step **43**.
- 43.** 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.*

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## Machine learning models

< Back to project

**What have you done?**

You've collected examples of numbers for a computer to use to recognise when numbers are top\_left, top\_middle or 7 other classes.

You've collected:

- 1 example of bottom\_left,
- 2 examples of bottom\_right,
- 2 examples of middle\_middle,
- 1 example of middle\_right,
- 1 example of top\_left,
- 2 examples of top\_right

**What's next?**

Keep going!

Go back to the [Train](#) page and collect more examples for each of the labels.

The more you can get, the better it should learn, but you need at least five examples of each as an absolute minimum.

- 44.** Leave the “Learn & Test” window open.  
Go back to the **Scratch** window.
- 45.** Play more games.  
*Try starting from a different position each time to get a variety of examples.*  
*Try starting from positions that you know you need more examples of.*

**46.** 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 44 and try again.*

The screenshot shows a web page titled "Machine learning models". At the top, there is a navigation bar with links: ml-for-kids, Welcome, About, Projects, Worksheets, News, Help, and Log Out. Below the navigation bar, there is a link "[< Back to project](#)". The main content area is divided into two sections: "What have you done?" on the left and "What's next?" on the right.

**What have you done?**

You've collected examples of numbers for a computer to use to recognise when numbers are top\_left, top\_middle or 7 other classes.

You've collected:

- 6 examples of bottom\_left,
- 5 examples of bottom\_middle,
- 8 examples of bottom\_right,
- 5 examples of middle\_left,
- 12 examples of middle\_middle,
- 8 examples of middle\_right,
- 5 examples of top\_left,
- 5 examples of top\_middle,
- 9 examples of top\_right

**What's next?**

Ready to start the computer's training?

Click the button below to start training a machine learning model using the examples you've collected so far.

(Or go back to the Train page if you want to collect some more examples first.)

At the bottom of the page, there is a box labeled "Info from training computer:" containing the text "Train new machine learning model".

**47.** Click the “**Train new machine learning model**” button at the bottom of the page.

## What have you done so far?

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

So far, 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. And you've 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 just going for the next empty space every time.

**48.** Close the Scratch window.

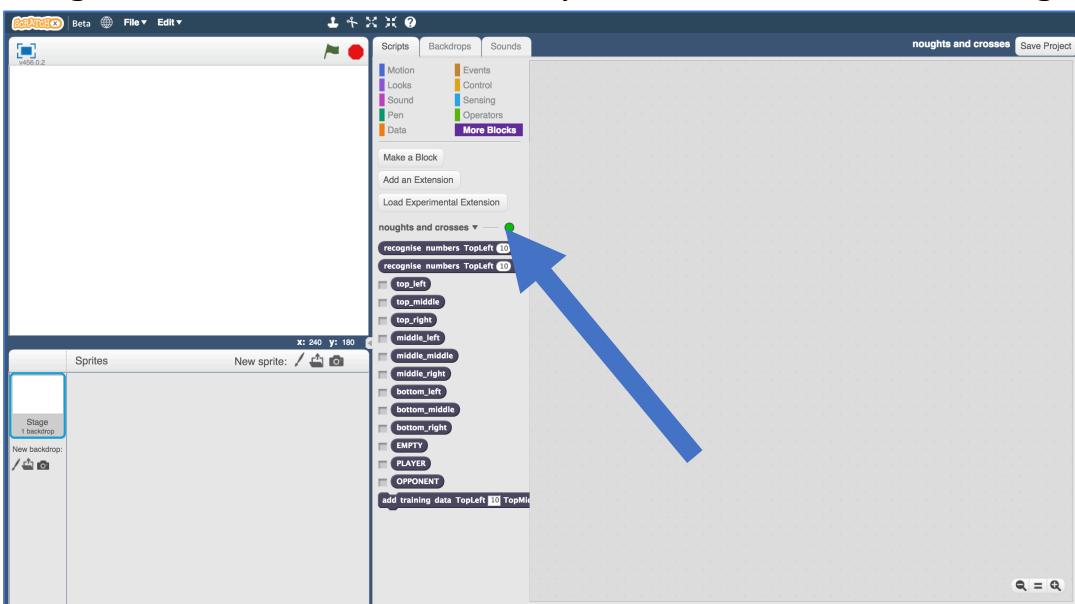
*Make sure you save your project first!*

**49.** In the training page, click the “< Back to project” link.

Then click the **Scratch** button.

**50.** Click the **Open in Scratch** button.

*The green circle means this time you have a machine learning model.*



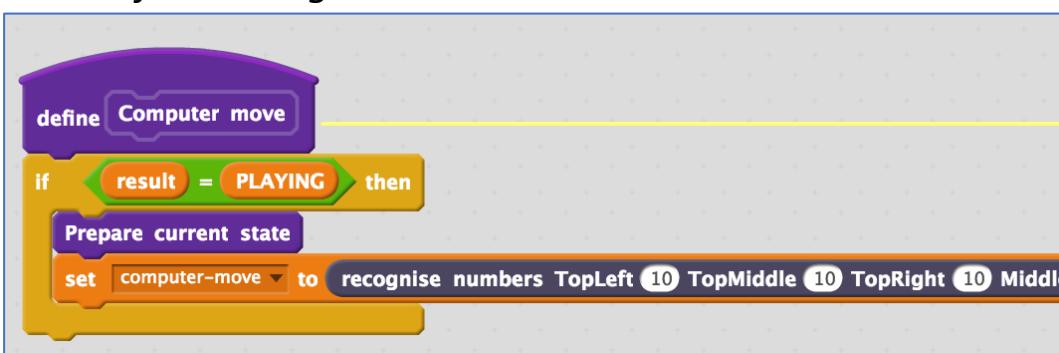
**51.** Open your saved project

*Click **File** -> **Load Project***

**52.** Click on the **Stage** and find the **Computer move** script

**53.** Modify the **Computer move** script so that it looks like this

*Use the first “recognise numbers” block that ends with “label”*



**54.** Add the current state for each space on the board to the “recognise numbers” block

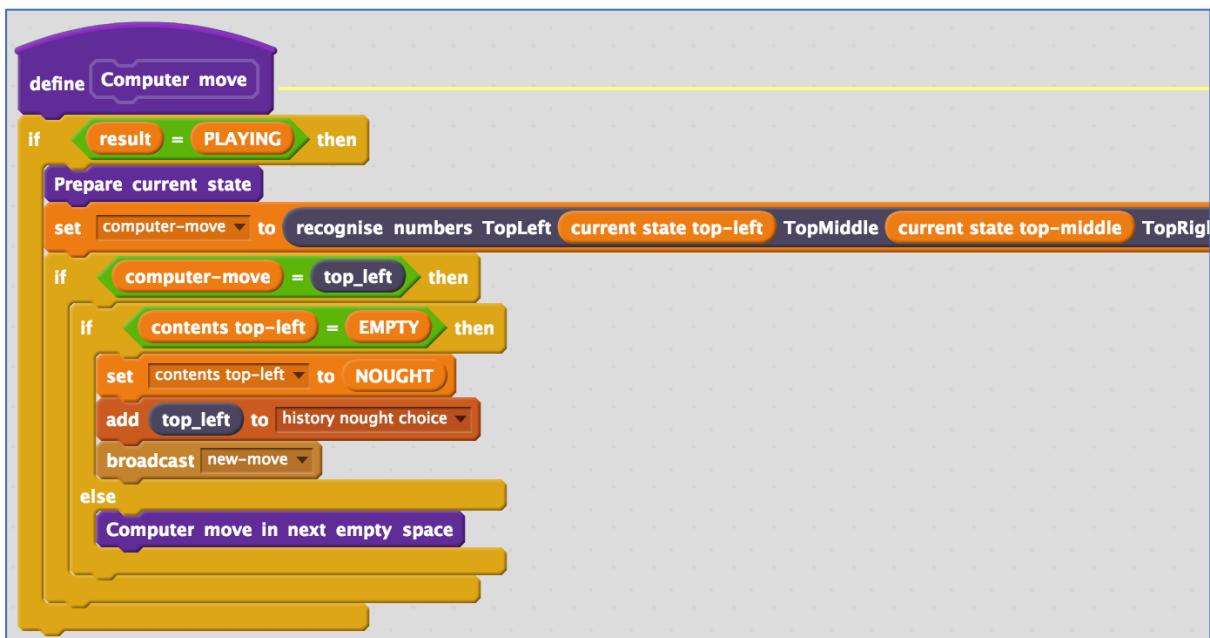


**55.** Modify the script to look like this

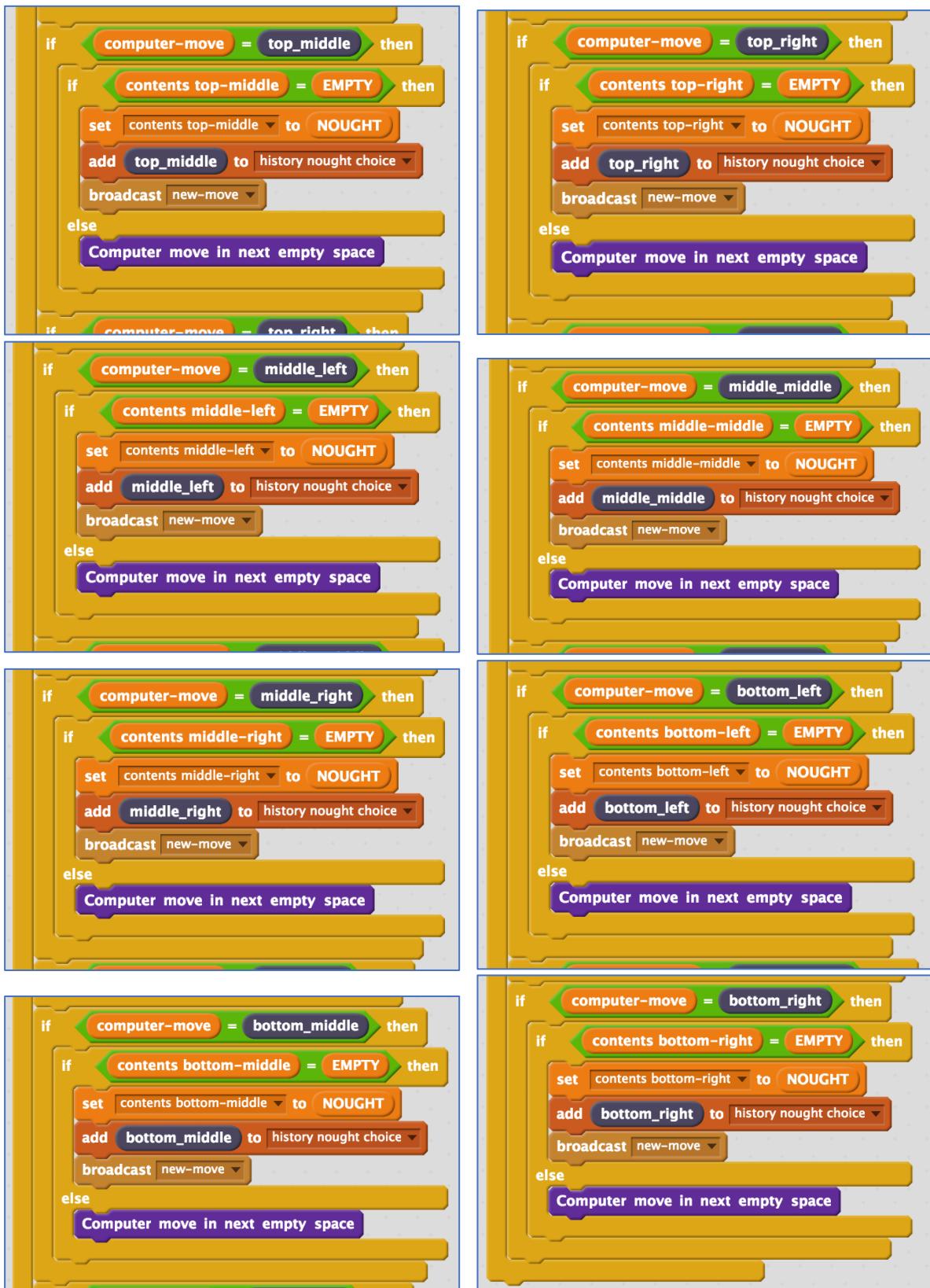
*This script will use the machine learning model to let the computer choose where to have a move... (as long as it chooses the top-left space).*

*While the computer is still learning, it may get things wrong. So there is also a check in the script to make sure that the computer has chosen an EMPTY space! If it's chosen a space that already has a nought or cross in, it'll just pick the next empty space.*

*It will also add the choice it's made to the history, so it can be used in training data if it ends up winning.*



## 56. Update the **Computer move** script to handle the other choices the machine learning model could make. This is all one long script. Duplicate the "if computer-move" block by right-clicking on it to save time.



## 57. The whole script should end up looking like this



## 58. Save your project

*Click **File** -> **Save Project***

## 59. Play against the computer by clicking on the **Green Flag**

*Use full-screen to avoid moving sprites accidentally.*

*Avoid playing the same game over and over again. Choose different spaces to give the computer a variety of examples of how to play.*

## 60. When it starts to feel like you're playing the same games over and over again, go back to the Learn & Test screen, and use the new examples you've collected

*Click the "**Train a new machine learning model**" button again*

The screenshot shows the 'Machine learning models' screen. At the top, there's a header bar with the title 'Machine learning models'. Below the header, there's a link '[< Back to project](#)'. The main area is divided into two sections: 'What have you done?' on the left and 'What's next?' on the right.

**What have you done?**

You've trained a machine learning model to recognise when numbers are top\_left, top\_middle or 7 other classes.

You created the model on Sunday, October 8, 2017 12:19 AM.

You've collected:

- 16 examples of bottom\_left,
- 14 examples of bottom\_middle,
- 19 examples of bottom\_right,
- 11 examples of middle\_left,
- 23 examples of middle\_middle,
- 15 examples of middle\_right,
- 11 examples of top\_left,
- 11 examples of top\_middle,
- 14 examples of top\_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 machine learning model and see what different the extra examples will make!

## 61. Every time you train a new machine learning model, you will need to re-open the Scratch project so that it starts using the new model.

*Click **File** -> **Load Project***

*Open your saved project, even though you already have it open!*

*Click **OK** when it asks if you want to replace the current project.*

*That will make sure you're using the latest model.*

## **62.** Go back to step 59 – and repeat

*Play against the computer, and try to vary your playing as much as possible.*

*Once you're struggling to keep coming up with new games, click the Train new machine learning model button again, and re-load your saved project in Scratch.*

*Try to repeat this process a few times until your machine learning model starts getting good!*

## 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.

## 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.

(The rules are in the Scratch game, but that doesn't count – that wasn't used in the machine learning model).

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.

## 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.

