

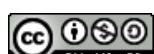
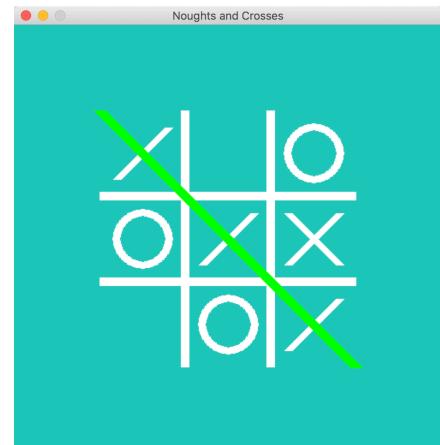
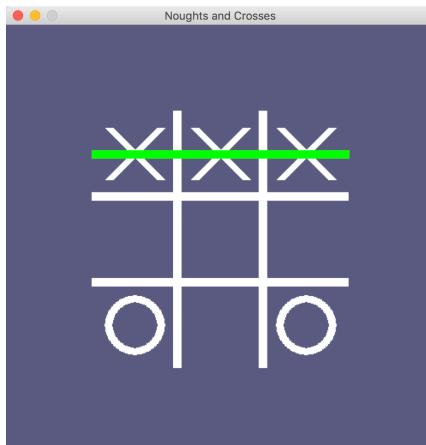
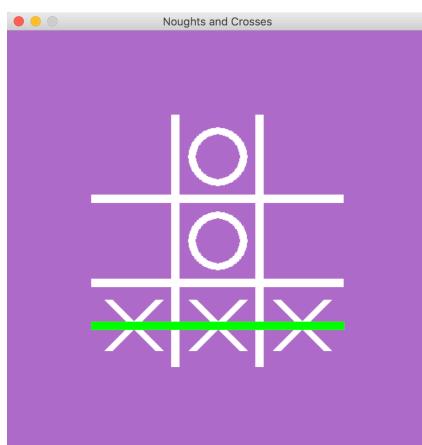
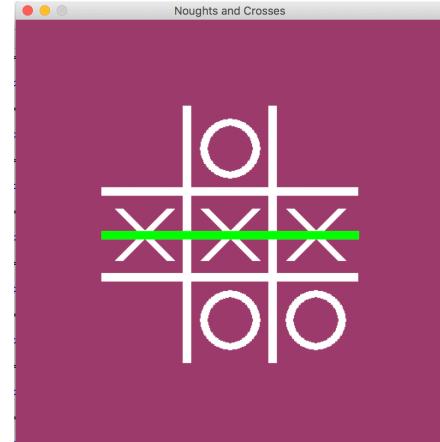
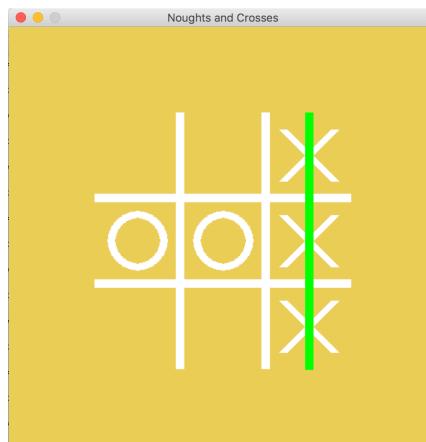
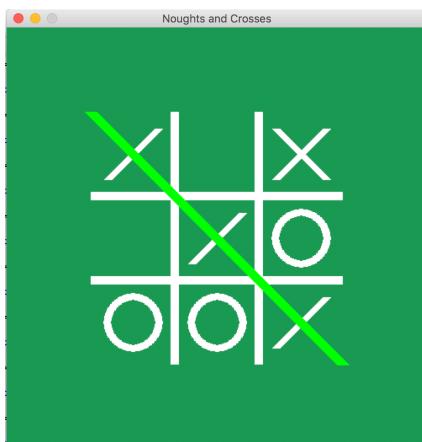


Noughts & Crosses

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

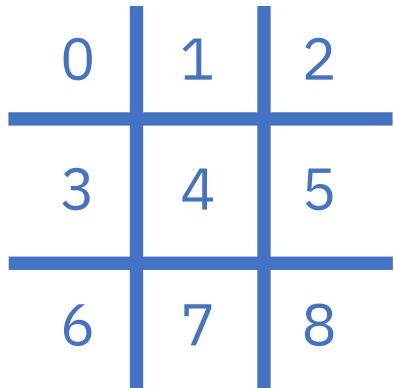
You won't give it instructions for how to play, or tell it what the objective or rules of the game are.

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 when it beats you.



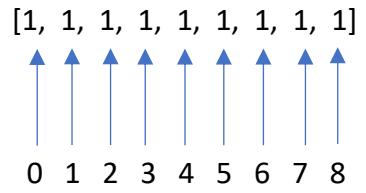
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Representing noughts and crosses in Python



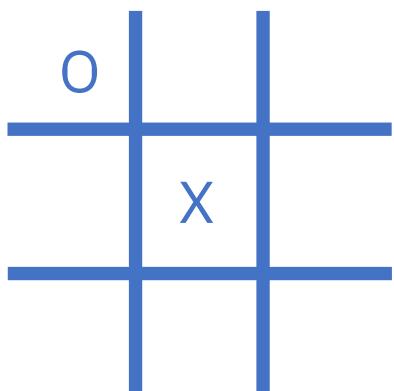
The positions of spaces on the noughts and crosses board are numbered from 0 to 8.

They are then stored in a list.



Empty = 1
O = 2
X = 3

An empty space is shown as a 1.
A nought O is shown as a 2.
A cross X is shown as a 3.



The board is represented as a list of 9 1's, 2's and 3's, one for each space

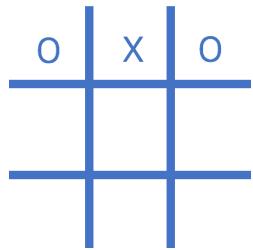
For example, at this point:

[2, 1, 1, 1, 3, 1, 1, 1, 1]

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.

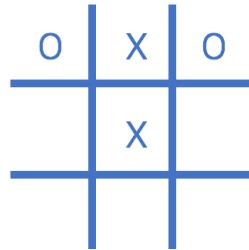


Imagine you decide to put your X in the centre space.

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

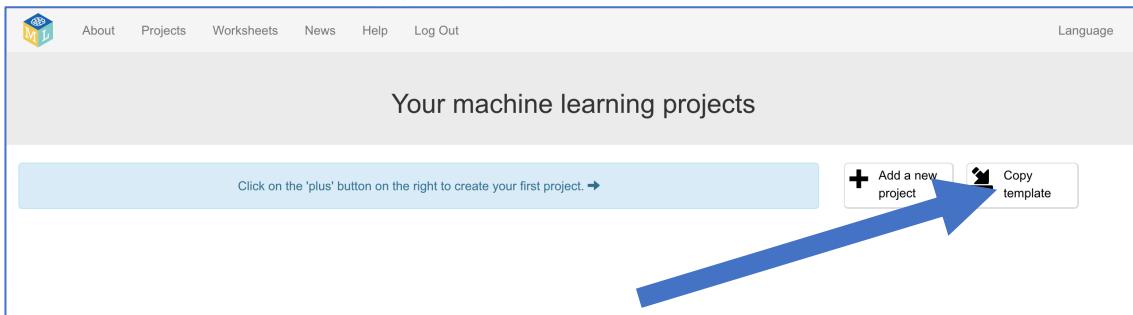
Using “opponent” and “player” instead of “nought” and “cross” means the computer can learn from both nought and cross moves.

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

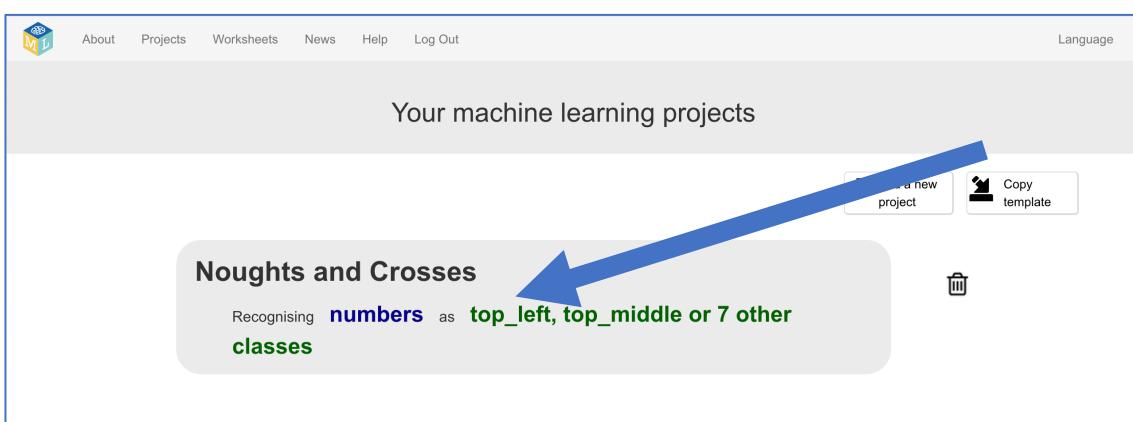
If you (X) win, you'll use your moves as examples to train the computer. If the computer (O) wins, you'll use the computer's moves to train with.

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

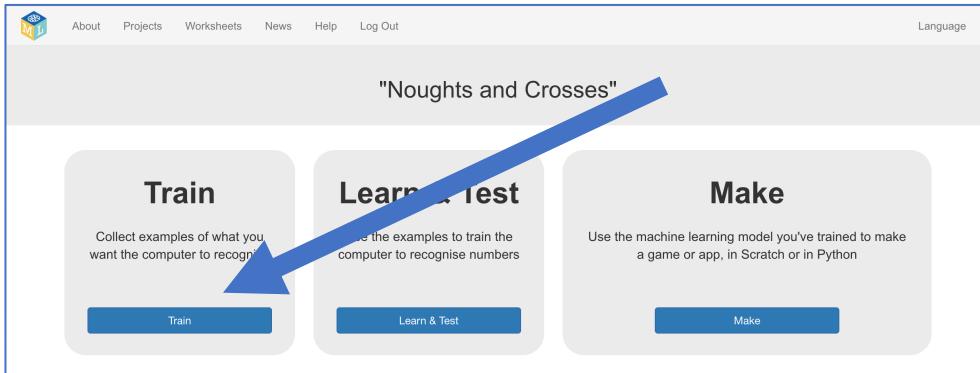
1. Go to <https://machinelearningforkids.co.uk> in a browser.
2. Click on “**Get started**”
3. Click on “**Log In**” and type in your username and password
If you don't have a username, ask your teacher to create one for you.
If you can't remember your password, ask your teacher to reset it for you.
4. Click on “**Projects**” on the top menu bar
5. Click on the “**Copy template**” button.



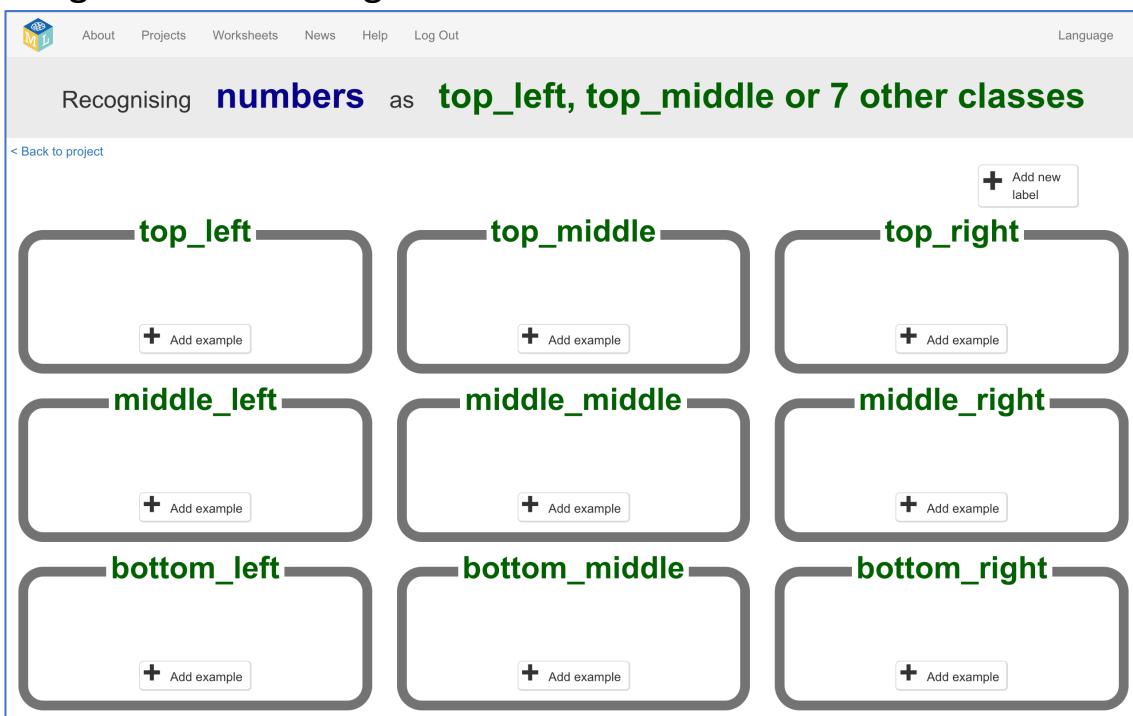
6. Import the “**Noughts and Crosses**” project template.
7. You should see “**Noughts and Crosses**” in your list of projects.
Click on it.



8. Click the “Train” button

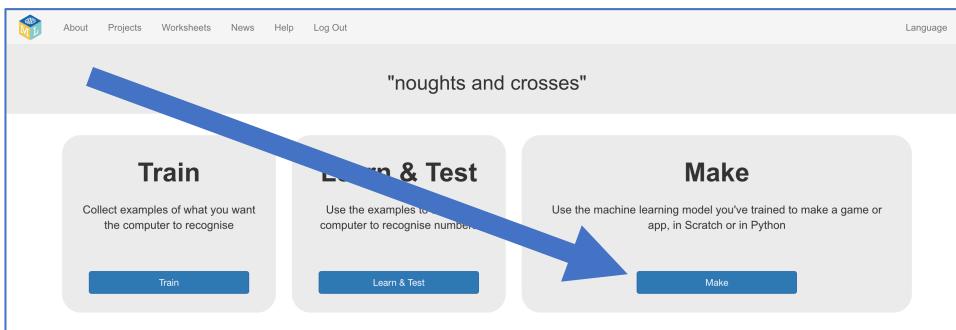


9. The template project has training buckets to store examples of noughts and crosses game moves.



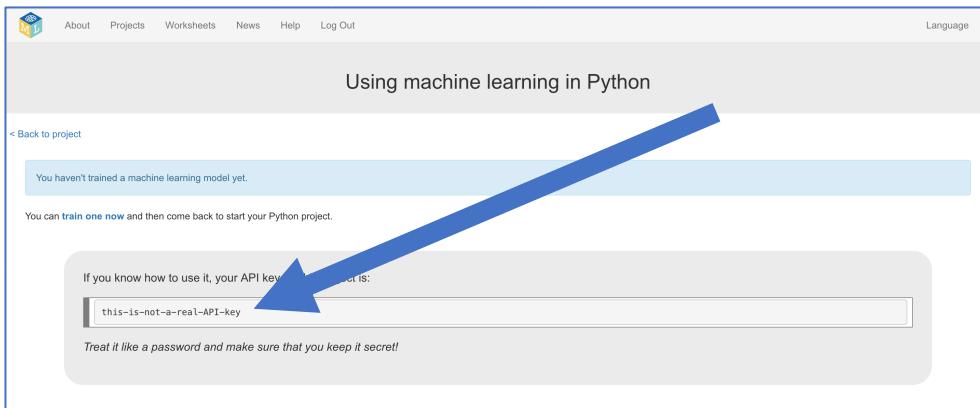
10. Click the “< Back to project” link.

11. Click on “Make”



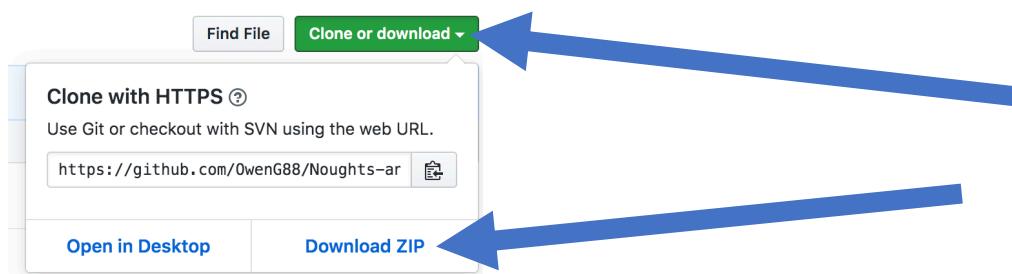
12. Click on “Python”

13. Find your project “API key”. You’ll need this code later.



14. Visit <https://github.com/dalelane/Noughts-and-Crosses>

15. Click the “Clone or download” button, then click “Download ZIP”



16. Unpack the ZIP and open the Python code in your preferred editor.

17. Paste the API key from Step 22 into the KEY variable

```
3 # This module is used to make HTTP requests to your machine learning model
4 import requests
5 # this module is used to choose a random colour for the user interface and
6 # make random choices about moves the computer should make
7 import random
8
9
10
11 # API KEY - the unique private code for your Machine Learning project
12 global KEY
13 KEY = "put-your-project-API-key-here"
14
15
```

The screenshot shows a Python script with several blank lines at the top. Line 11 starts with "# API KEY - the unique private code for your Machine Learning project". Line 12 is "global KEY". Line 13 is "KEY = "put-your-project-API-key-here"". A blue arrow points to the line "KEY = "put-your-project-API-key-here"".

18. Make sure you have **requests** and **pygame** installed.

Ask your teacher if you don't know how to do this.

19. Run the Python program.

Play a game of noughts and crosses against the computer.

Your machine learning project will be choosing where to make it's moves at random.



20. Look at the output from the Python program after the game ends.

Next, you will edit the Python program so that the moves made by whoever wins the game are used to train your machine learning model.

```
HUMAN won the game!
Maybe the computer could learn from HUMAN's experience?

At the start of move 1 the board looked like this:
['EMPTY', 'EMPTY', 'EMPTY', 'EMPTY', 'EMPTY', 'EMPTY', 'EMPTY', 'EMPTY', 'EMPTY']
And HUMAN decided to put their mark in bottom_left

At the start of move 2 the board looked like this:
['COMPUTER', 'EMPTY', 'EMPTY', 'EMPTY', 'EMPTY', 'HUMAN', 'EMPTY', 'EMPTY', 'EMPTY']
And HUMAN decided to put their mark in middle_middle

At the start of move 3 the board looked like this:
['COMPUTER', 'EMPTY', 'EMPTY', 'HUMAN', 'EMPTY', 'HUMAN', 'EMPTY', 'COMPUTER']
And HUMAN decided to put their mark in top_right
```

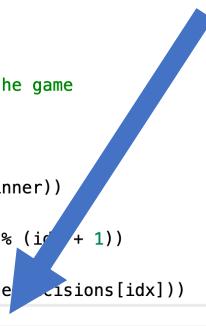
21. Find the `learn_from_this` function

It is printing out the moves made by whoever won the game.

```
184
185
186 # Someone won the game.
187 # A machine learning model could learn from this...
188 #
189 # winner      : who won - either HUMAN or COMPUTER
190 # boardhistory : the contents of the game board at each stage in the game
191 # winnerdecisions : each of the decisions that the winner made
192 def learn_from_this(winner, boardhistory, winnerdecisions):
193     print("%s won the game!" % (winner))
194     print("Maybe the computer could learn from %s's experience?" % (winner))
195     for idx in range(len(winnerdecisions)):
196         print("\nAt the start of move %d the board looked like this:" % (idx + 1))
197         print(boardhistory[idx])
198         print("And %s decided to put their mark in %s" % (winner, winnerdecisions[idx]))
```

22. Add a line in the `for` loop so each move is added to your project training data

```
184  
185  
186 # Someone won the game.  
187 # A machine learning model could learn from this...  
188 #  
189 #   winner      : who won - either HUMAN or COMPUTER  
190 #   boardhistory : the contents of the game board at each stage in the game  
191 #   winnerdecisions : each of the decisions that the winner made  
192 def learn_from_this(winner, boardhistory, winnerdecisions):  
193     print("%s won the game!" % (winner))  
194     print("Maybe the computer could learn from %s's experience?" % (winner))  
195     for idx in range(len(winnerdecisions)):  
196         print("\nAt the start of move %d the board looked like this:" % (idx + 1))  
197         print(boardhistory[idx])  
198         print("And %s decided to put their mark in %s" % (winner, winnerdecisions[idx]))  
199         add_to_train(boardhistory[idx], winner, winnerdecisions[idx])  
200  
201
```



23. Run your Python program again and play another game.

24. Go back to the training page

Leave the Python window to go back to the training tool window. Click the “< Back to project” link and then click “Train”

The screenshot shows a training interface for a 3x3 board. There are six items labeled: top_left, top_middle, top_right, middle_left, middle_middle, and middle_right. Each item has a 'Add example' button. The top_right item shows a 3x3 board state with labels for each square: TopLeft, TopMiddle, TopRight, MiddleLeft, MiddleMiddle, MiddleRight, BottomLeft, BottomMiddle, and BottomRight. The labels indicate the state of each square: EMPTY, OPPONENT, or PLAYER.

25. 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.

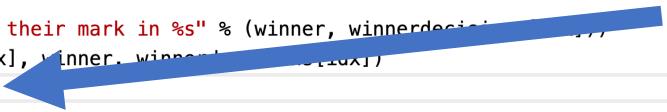
This is collecting training data, but you still need to use it to train a machine learning model.

26. Edit the `learn_from_this` function again to add a new line

The new line will use the training data collected so far to create a new machine learning model.

Make sure you get the indenting right so you only train a model after adding all of the moves.

```
189 # winner : who won - either HUMAN or COMPUTER
190 # boardhistory : the contents of the game board at each stage in the game
191 # winnerdecisions : each of the decisions that the winner made
192 def learn_from_this(winner, boardhistory, winnerdecisions):
193     print("%s won the game!" % (winner))
194     print("Maybe the computer could learn from %s's experience?" % (winner))
195     for idx in range(len(winnerdecisions)):
196         print("\nAt the start of move %d the board looked like this:" % (idx + 1))
197         print(boardhistory[idx])
198         print("And %s decided to put their mark in %s" % (winner, winnerdecisions[idx]))
199         add_to_train(boardhistory[idx], winner, winnerdecisions[idx])
200     train_new_model()
201
202
```



27. Play several more games.

Your changes to the code mean that after every game finishes, the moves made by the winner are added to the training data as examples of how to win, and a new model is trained using all examples collected so far.

The longer you play, the more the computer can learn from you, and the better it should get.

28. Go back to training page and look at all of your training examples

You will need to refresh the page to see them.

29. Go to the Learn & Test page

Click the “< Back to project” link and then click “Learn & Test”

Check when your code last trained a machine learning model

Try putting in some numbers to see how it is recognised based on your training.

TopLeft	EMPTY
TopMiddle	EMPTY
TopRight	EMPTY
MiddleLeft	EMPTY
MiddleMiddle	EMPTY
MiddleRight	EMPTY
BottomLeft	EMPTY
BottomMiddle	EMPTY
BottomRight	EMPTY

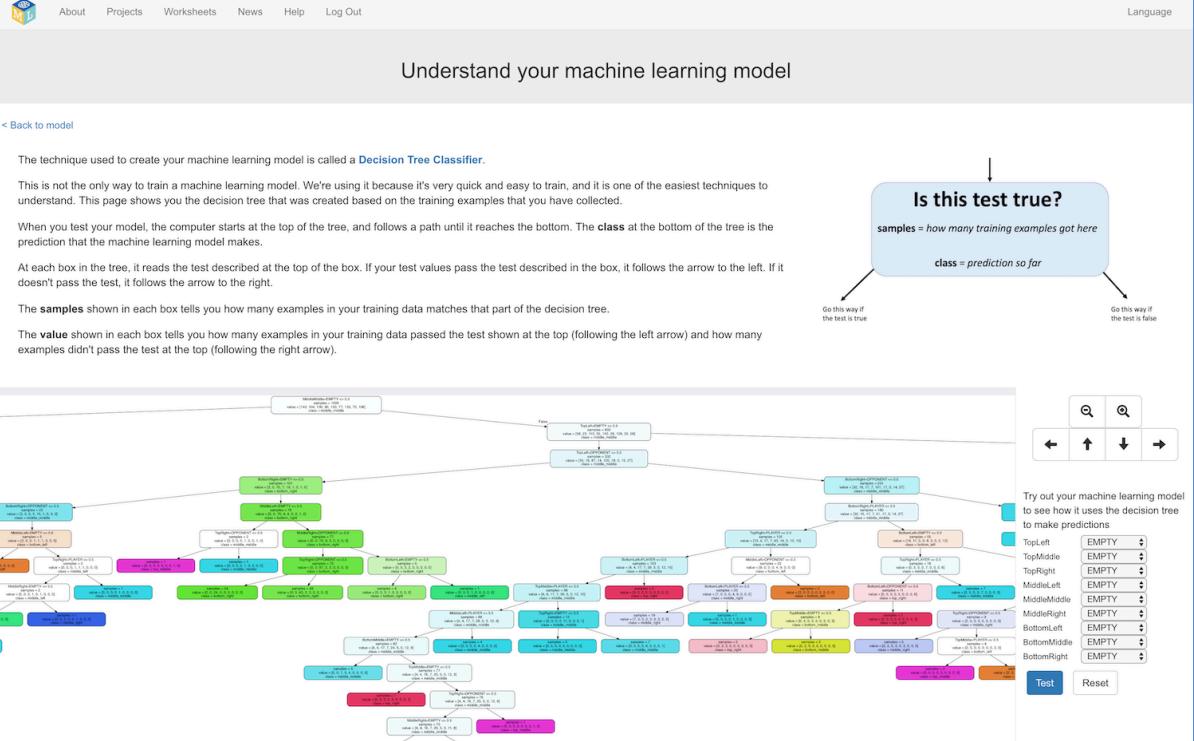
Test **Describe your model** (beta)

Info from training computer:

Model started training at: Sunday, September 1, 2019 11:11 AM
Current model status: Available

Delete this model

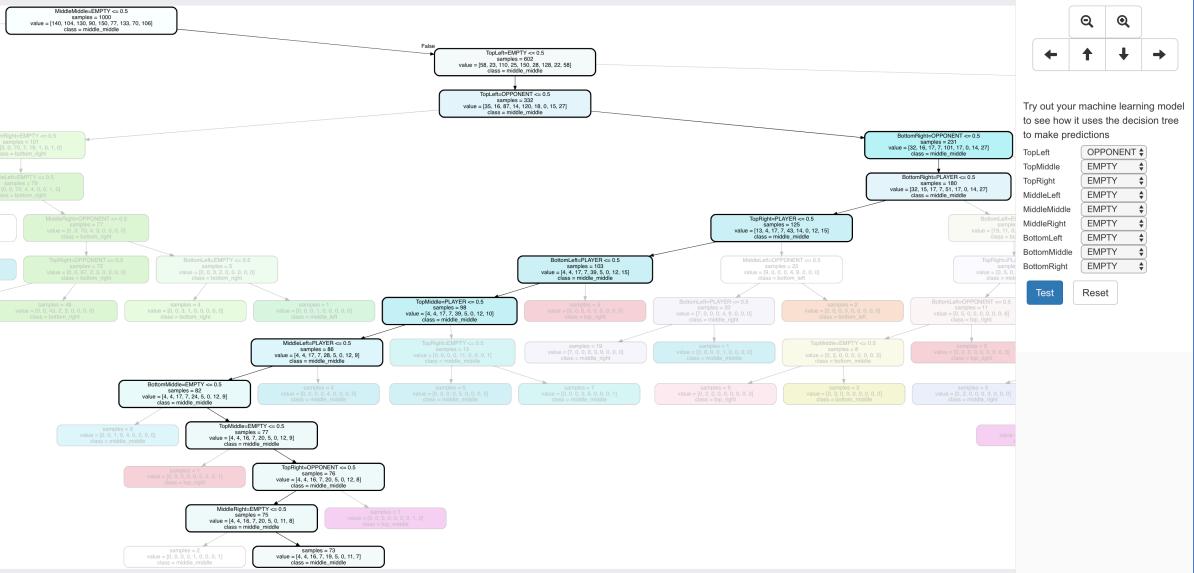
30. Click “Describe your model” to see how your model works

MLflow interface showing a decision tree classifier for a machine learning model. The top navigation bar includes About, Projects, Worksheets, News, Help, Log Out, and Language. The main title is "Understand your machine learning model". Below it, a note says "The technique used to create your machine learning model is called a **Decision Tree Classifier**". A detailed description follows:

- This is not the only way to train a machine learning model. We're using it because it's very quick and easy to train, and it is one of the easiest techniques to understand. This page shows you the decision tree that was created based on the training examples that you have collected.
- When you test your model, the computer starts at the top of the tree, and follows a path until it reaches the bottom. The **class** at the bottom of the tree is the prediction that the machine learning model makes.
- At each box in the tree, it reads the test described at the top of the box. If your test values pass the test described in the box, it follows the arrow to the left. If it doesn't pass the test, it follows the arrow to the right.
- The **samples** shown in each box tells you how many examples in your training data matches that part of the decision tree.
- The **value** shown in each box tells you how many examples in your training data passed the test shown at the top (following the left arrow) and how many examples didn't pass the test at the top (following the right arrow).

A large decision tree diagram is displayed, with nodes representing tests like "TopLeft-EMPTY == 0.5" and "TopLeft-OPPONENT == 0.5". The tree structure is complex, with many branches and leaf nodes. To the right of the tree, there is a "Test" panel with dropdown menus for board positions (TopLeft, TopMiddle, etc.) and a "Test" button. A callout box "Is this test true?" explains the meaning of "samples" and "class".

31. Describe a state of the board on the right and click “Test” *The visualisation describes how your model decides where to move.*

MLflow interface showing a decision tree classifier for a game board state. The top navigation bar includes About, Projects, Worksheets, News, Help, Log Out, and Language. The main title is "Understand your machine learning model". Below it, a note says "Try out your machine learning model to see how it uses the decision tree to make predictions". A detailed description follows:

- The board state is defined by the following variables:
 - TopLeft-EMPTY == 0.5
 - TopLeft-OPPONENT == 0.5
 - TopMiddle-EMPTY == 0.5
 - TopMiddle-OPPONENT == 0.5
 - MiddleLeft-EMPTY == 0.5
 - MiddleLeft-OPPONENT == 0.5
 - MiddleMiddle-EMPTY == 0.5
 - MiddleMiddle-OPPONENT == 0.5
 - MiddleRight-EMPTY == 0.5
 - MiddleRight-OPPONENT == 0.5
 - BottomLeft-EMPTY == 0.5
 - BottomLeft-OPPONENT == 0.5
 - BottomMiddle-EMPTY == 0.5
 - BottomMiddle-OPPONENT == 0.5
 - BottomRight-EMPTY == 0.5
 - BottomRight-OPPONENT == 0.5
- The board state is represented as a 3x3 grid of values from 0 to 100.
- The decision tree starts at the root node "TopLeft-EMPTY == 0.5". It branches into "TopLeft-OPPONENT == 0.5" (samples = 30, value = 23, 110, 25, 150, 28, 120, 22, 58) and "TopLeft-OPPONENT == 0.0" (samples = 26, 16, 97, 14, 100, 15, 16, 27). The "OPPONENT" branch leads to a series of nodes for different board configurations, such as "TopMiddle-OPPONENT == 0.0" and "MiddleLeft-OPPONENT == 0.0".
- Each node provides information about the number of samples that pass the test and the resulting value.

32. Keep playing until you start to see the computer get better *How does that change the machine learning model you create?*

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.

(The rules are in the Python code so it can be displayed but aren't used in the machine learning model).

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.

