Evolving Artificial Neural Networks To Play Games

**Preface**

We use Artificial Neural Nets(ANNs) to control a “cart” within a simulated environment. The environment is essentially a game, where the performance of the ANN is scored by how long it can use its control of the cart to balance a pole on top of it. We then use the ANNs with the best scores to make new generations of ANNs, and repeat the process in an attempt to evolve the ANNs by way of natural selection.

**Introduction**

An Artificial Neural Net is a collection of nodes, and connections, that are put together to simulate the theoretical workings of neurons found in biological entities. From a programming perspective, a ANN receives a number of inputs from a number of sources that are given different weights, the ANN then decides on an output. In the Simulated environment in this project there are two possible inputs the ANN can output: move to the left or move to the right. For every frame of the “game”, the ANN is given all the parameters of the scene and give an output.

**Our Solution to the Problem – A Brief Description of the Code**

The submitted code consists of three python scripts. Two of them contain a class, the ANN class and a GA class. They are described in more detail below. The last script defines all necessary parameters, define the desired class objects and starts the training, simulation and comparison. Wherever applicable, vectorized methods have been preferred to perform the operations needed.

Every artificial neural network in every generation is an object from the ANN class. The GA class at any time holds the current generation of ANNs and has functions to evaluate them and create a new generation of ANNs for as many generations as has been specified. We only need one GA object to complete the task set out in this project.

**ANN Class**

The ANN class is made as a subclass of the MLPClassifier class.

At initialization, in addition to creating an MLPClassifier object, it is also passed the CartPole environment. The number of hidden layers can be passed as a parameter, or it will be set automatically, according to the function provided in the assignment text. In our implementation, 4 input nodes would give 4 hidden layer nodes. When initialized, the ANN also partially trains itself using a random action, and the initial state of the CartPole environment. This is to get a starting point, and the correct shape for the weights and biases. The initial state of the environment is returned by env.reset(). Initially all observations are assigned a random value in range [-0.05, 0.05]. This is different from the assignment text suggestions, where a random sample from the observation space was used for partial training.

There are three major operations that this class is responsible for, in addition to storing the weights, biases and MLPClassifier. First, this class runs the simulation for itself on the CartPole environment. Second, its also performs crossover on itself and another ANN, in that case you pick one and pass the other as a parameter. Third, it performs mutations on its weights and biases.

The method for running the simulation will record observations from the environment and predict and perform actions for each timestep until the environment either fails, if the pole falls or the cart hits the boundary, or the maximum amount of iterations/timesteps have passed. The maximum number of iterations is set as default to 10 000. If the render parameter is set to True, the environment is rendered for every timestep. It is set to False as default, because it will take too long to render during the training of the ANNs.

The method also counts repeat actions, and checks whether an action has been repeated more than the desired maximum repetition. If it has, a random action is performed in the next step. The counter is reset if the random action is different from the previous.

If the parameter partial\_fit is set to true, the ANN will do a partial fit at the end of each step, using the current observation of the environment and the predicted action. It is set to False as default, and we did not use this ability. It is briefly discussed in the results section of the report.

At the end, a reward property is given to the ANN object, which is set to +1 for every timestep completed before the simulation ended.

**GA Class**

The GA class was made to initialize and hold a generation of ANNs, run the simulation for the environment for all of them, and then generate a new generation of ANNs based on the results. The environment and needed parameters are held as properties for the objects. The first generation is initialized and trained. The population of ANNs at any generation is held in the property self.population.

After initializing a GA object, the run() method is used to start the process. The best agent from the generation is stored, fitness of the current/first generation is printed and stored. A new generation is created with parents chosen with probabilities based on the ANNs rewards. Again, the best agent from the generation is stored, fitness of the current/first generation is printed and stored. This is repeated for the specified number of generations. that will stop the running when an ANN has reached the max iterations and then also a reward equal to the max iterations, without failing.

In the method that creates the child ANNs, the breed() method, the mutation rate is either given as a float, or it can be given as a callable function. If a lambda function is passed, the function will take the average reward of the parent ANNs and calculate a mutation rate based on this. This way, we can make a lambda function that gives a smaller mutation rate for high performance ANNs and a higher mutation rate for low performance ANNs.

After running all the generations, we can render the best ANN from the latest generation using the render\_best() method. This will

Method for rendering average?

**Crossover**

When the GA class defined in *Genetic\_algoithm.py* calls the *new\_generation(self)* method, it will call *select\_n\_from\_distribution(2)*, to randomly pick two ANNs as parents from the latest generation with probabilities defined by calling *get\_relative\_fitness(self).* Parent1 and parent2 are cloned to child1 and child2. The code then uses methods defined in the DNA class defined in *dna.py* to alter the variables of child1 and child2. *new\_generation* then calls *self.dna.combine(child1.get\_genes(), child2.get\_genes(), score)*.

*get\_genes(self)* is defined in *neural\_network.py*, and merges the *coefs* and *intercepts* defined by the *MLPClassifier,* representing all weights and biases, into one array.

The combine method then calls *crossover(self, dna1, dna2)*. crossover calls *\_crossover\_row(self, row1, row2,)* to do one of three defined crossover operations.

one-point:

The two rows are split in two somewhere at random, and two new rows are made using these four parts. One part is made with the first part of row 1 and the second part of row 2, the other is made with the opposite.

two-point:

Much like "one-point”, except the rows are divided into three parts at random. One of the new rows would be made from the first part of row 2, the second part of row 1 and the third part of row 2. Vice versa for the other new row.

uniform:

Uniform crossover assigns a 50% chance to each variable in the row that they be one of two parts used to make the new rows. The new rows are then made much like how the one-point split is made.

In our code, these methods are realized by using a mask of index numbers using *slice()* for one or two point crossover, and using an array of Boolean values for the uniform crossover.

If the class variable *dna.crossover\_ravel* is set to True, then the *crossover\_row* method will try to turn input matrices into numpy arrays.

The *new\_generation* methods runs a loop self.n/2 times, where n is the size of the generations we have defined at startup

This is all illustrated in the figure below.

ILLUSTRATION

**Mutation method**

The methods for performing mutations will change the weights and biases depending on the probability described by the mutation rate. There is a possibility to pass a lambda function as a mutation rate, which is described in the GA class, where this is handled.

The way the mutation is done differs from the suggestion in the assignment. Here, the probability for every weight to mutate is set equal to the mutation rate by making a mask of boolean values. If a random number representing a weight is below the mutation rate. The mutation will be performed.

Unlike the suggestion, a mutation is not performed by switching weights between children ANNs. A few different options for mutation have been implemented and can be chosen by commenting/uncommenting the desired option. The option being used in the code is one which adds a small number to the weight to be mutated. The number added is normally distributed with expectation 0 and standard deviation 1, .

There is also a clone function, that makes a new ANN with deep copies of the same weights and biases. This is used to initially make the child ANNs from the parents before crossover and mutation.

Results

**Ronny Wathne**

Discussion of final code and choice of methods

Report writing

Planning of presentation

Preparation for presentation

**Kristian Fredrik Molina**

Initial discussions and planning of project

Organising group communication

Review of code

Preparation for presentation

**Ivica Kostric**

Initial discussions and planning of project

Wrote and implemented final version of code

Classes for ANNs and generations of ANNs with necessary functions

Discussion of final code and choice of methods

Testing different implemented genetic algorithms

Planning of presentation

**Andreas Nesse**

Initial discussions and planning of project

Wrote preliminary code script - following assignment suggestions

Functions for simulating ANNs and creating new generations

Discussion of final code and choice of methods

Report writing

Making presentation slides and structure

**Clement Couronne**

Review of code

Preparation for presentation