ENPM690

Robot Learning

Term project on:

Autonomous Driving Vehicle

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Abstract

Autonomous driving vehicle are vehicles capable of sensing their environment and safely acting upon it without or little human input. There various levels of autonomous vehicles-

1 Level 1: Vehicle is capable of Cruise control, Lane keeping, Emergency braking. Driver cannot to anything else while driving, full attention is required.
2 Level 2: Vehicle is capable of doing everything required but need driver to be attentive if something is going wrong. Hands on wheel is required. Tesla's autonomous driving is currently at level 2.
3 Level 3: Vehicle is capable of driving on its own and driver does not need to be looking at road.
4 Level 4: Vehicle is capable of complete autonomous driving and driver can fall asleep while travelling, but on known roads. Autonomous driving cars of Waymo are trying to achieve this level.
5 Level 5: Vehicle is capable of driving on any road under any condition. Steering wheel is optional in such vehicles.

Chapter 1

Introduction

1.1 Motivation

Autonomous driving vehicle is future of transportation. Every year thousands of people die in road accidents, most of which are caused due to human errors. These can be reduced by switch to autonomous. Make vehicles truly autonomous there is need of a machine learning component which can take decision and learn from experiences. As, every possible situation a vehicle might encounter in real world is impossible to program.

This task can be divided into 2 main sections-

1 Perception- Perception is the first step. This is to interpret the data coming from sensors like camera, LIDAR, etc. various computer vision algorithms are used for perception tasks, like recognizing other vehicles, obstacles and traffic signs. The vehicle should be able to detect these without fault in all different sorts of conditions like night, haze, snow, etc.

2 Decision making- Decision making is second step. After detecting something what action should the vehicle take.

The generalization of approach is necessary. It is the ability of the model to fit into unseen instance. Artificial Neural Networks is the current most promising mechanism which can be used for generalization. Hence, it can be used to generalize the decision-making process of the vehicle.

1.2 Aim

Aim is to train a Neural Network using evolutionary mechanism in reinforcement environment. The neural network has 5 nodes in input layer each one for sensor and 2 nodes in output layer for forward motion and steering.

In this project we will take data from distance sensor and act upon it, using neural network for taking decision. Perception part like cleaning the data from sensors is out of scope of this project.

Chapter 2

Robot Description

Robot is four wheeled with non-Holonomic constraints. Rear 2 wheels of the robot provide power and front 2 wheels of the robot control the direction of car.

2.1 Link parameters and constraints

Links:

1. Ratio of distance between wheels (W/L): 5/7

Joint Constraints:

1. Front wheels along steering axis: -25° to 25°

2.2 Assumptions

1. Lateral friction between the robot and the ground is infinite. Robot cannot drift.
2. There is no rolling resistance or air resistance. If the robot is set in motion it will not stop due to these losses. It will have to apply brakes.
3. Sensor has enough range for vehicle to react. Sensor range should not be less than turning radius of robot.
4. There is linear mapping between input of robot for power (output of neural network) and the velocity it is travelling.
5. There is linear mapping between input of robot for turning (output of neural network) and the current angle of front wheels with respect to car.

Chapter 3

Methodology

3.1 Approach

3.1.1 Artificial Neural Networks

Artificial Neural Networks are computing system inspired from the biological working of animal brains. These are used to perform tasks which required to design very specific rules to be execute but, without specifying them. Performance of neural networks iteratively improved using different mechanism such as Backpropagation or Evolutionary Algorithms without knowing how to solve the given problem just based on performance matrix.

3.1.2 Evolutionary Algorithms

Evolutionary Algorithms uses mechanism inspired form the natural process of evolution and natural selection. Population is generated and the fittest individual survive to reproduce. It is divided in 3 main steps: -

1 Selection- Selection is process of determining the performance of each individual and selecting it for next generation.

2 Recombination- Recombination is the process to create next generation. Fit individuals are crossed to create new individual. This is done is sexual evolutionary algorithm, asexual evolutionary algorithm uses mutation to generate next generation.

3 Mutation- Mutation is done to maintain the genetic diversity. This avoids getting stuck at local maximum.

3.1.3 Evolutionary Neural Network

Artificial Neural Network is used in conjunction to Evolutionary Algorithm. A population of ANNs is created at random and tested in the environment. A portion of best performing individuals are retained, and rest are deleted. The population is the again created to initial number by creating new individuals by inducing mutation in the best performing individuals. This is repeated for a predefined number of generations.

There are multiple check points set in the training environment. Reaching the check point rewards the individual with points. Individual dies if it hits the wall.

3.2 Implementation

3.2.1 Neural Network

For the training the neural network is defined has 4 fully connected layers input layer has 5 neurons each for a senor input and 2 neurons for acceleration and turning. Middle 2 layers are hidden layers each with 10 neurons each. Each connection between any neuron has a weight associated to it, which is multiplied to the signal while feed forward. “Tanh” activation function is used before passing the signal to next neuron. Tanh is used because it preserves the negative part of a signal, other activation function cut out negative values. And in our case, negative represents the opposite direction.

Each neuron is represented by: -

$$signal = \tanh\left(\sum_{i=1}^{n} x_i w_i\right)$$

Where n is number of neurons in previous layers, x is signal from neuron in previous layer and w is weight associated to it.

3.2.2 Evolutionary mechanism

A population of 10 individuals is created while training. If all the candidates die or current generation is 60 seconds old, then new population is generated. To generate new population, 5 of the best performing candidates of last generation are kept and rest 5 are created by inducing mutations in these individuals. There are 4 types of mutations used: -

1. Flip the sign.
2. Randomly select new weight.
3. Increase by a random factor.
4. Decrease by a random factor.

There is 20% change of each mutation for each weight. This was repeated for 150 generations when the desired performance was achieved.

Chapter 4

Simulations and Results

Initial expectation was that the vehicle will travel in the center of track which the safest possible position to be as shown in figure below: -

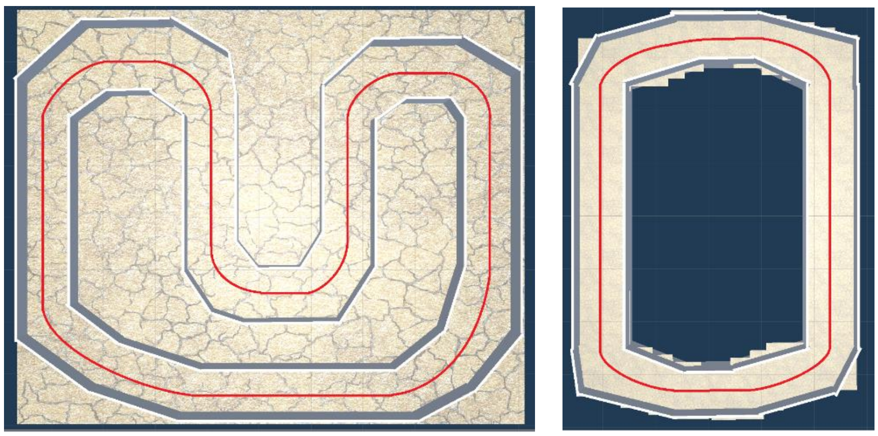

Figure 1) Expected path

This result was achieved about 50 generation. But, at about 150 generation it began to follow racing lines which are the fastest possible way on the track. Racing line are the most optimal path possible on a track. The vehicle has to be on the outer side of the track in straight sections and on the inner side of the track on turns. This result in the maximum turning radius possible hence, the vehicle slow down can be kept minimum. The vehicle followed the track as shown in figure below: -

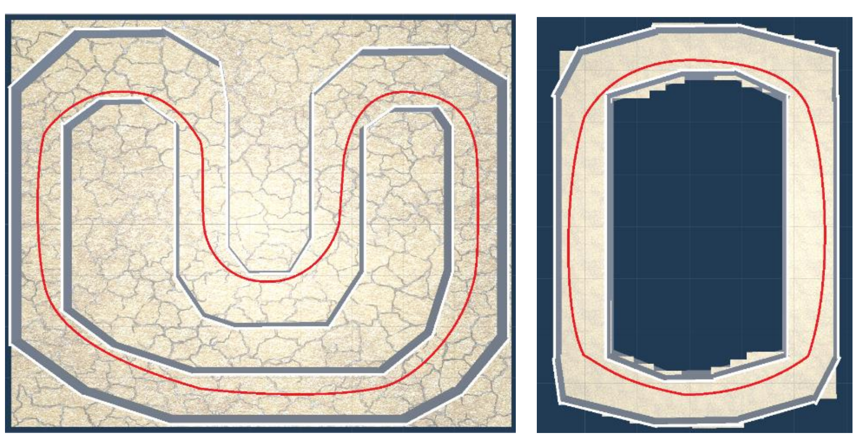

Figure 2) Racing lines

Chapter 5

Conclusion and Future Scope

5.1 Conclusion

Evolutionary neural network can be used for decision making of an autonomous driving vehicle. Usually, autonomous driving car incorporate fusion of sensors such as camera and ultra-sonic sensors. In worst case scenario if camera fails and there is no video input, then the vehicle can be safely operated and stopped at a safe spot, purely with the feedback of distance sensors.

5.2 Future Scope

More complex version of the such network with multiple hidden layers and more input and output nodes, can be trained in complicated environment similar to real world and be used in autonomous driving vehicles. In current scenario the obstacles(walls) are static. Training can be done on dynamic obstacles. Current system configuration includes 5 distance sensors, which looks at a certain direction and only give feedback if an obstacle comes in front of the narrow ray emitted by the sensor. Instead similar system can be trained with sensors like Lidar which can give better view of the surrounding to the car.

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Project GitHub Repository: - https://github.com/ToyasDhake/Autonomous-Driving-Vehicle
Output video: - https://www.youtube.com/watch?v=dWk-vWELtQw