People's Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

University M'Hamed BOUGARA – Boumerdès

Institute of Electrical and Electronic Engineering Department of Electronics

Machine Learning Based Adaptive Impedance Control

Masters Degree Project

Author: Benbouali Mohamed Amine

Supervisor: Ms. Derragui Nabila

Simulation Update

Genetic Algorithm Training Process:

In order to train a neural network using genetic algorithms, control of the system must be given to the network, in our case the neural network has control of the gains of the Impedance Control System, and as input, the neural network takes the interaction force, throughout the training process the neural network is encouraged to minimize interaction force by the policy function we described, in this case the policy function punishes the machine learning model's fitness function for increasing interaction force with the environment and rewards its fitness function for decreasing the interaction force, our neural network's cost function (activation function) is reLU as shown in figure 1, it is suited for our gains prediction as it does not predict negative values for the gains and is not biased towards maximum extremities as described by the straight increasing line, compared to typically used activation functions such as Sigmoid and TanH

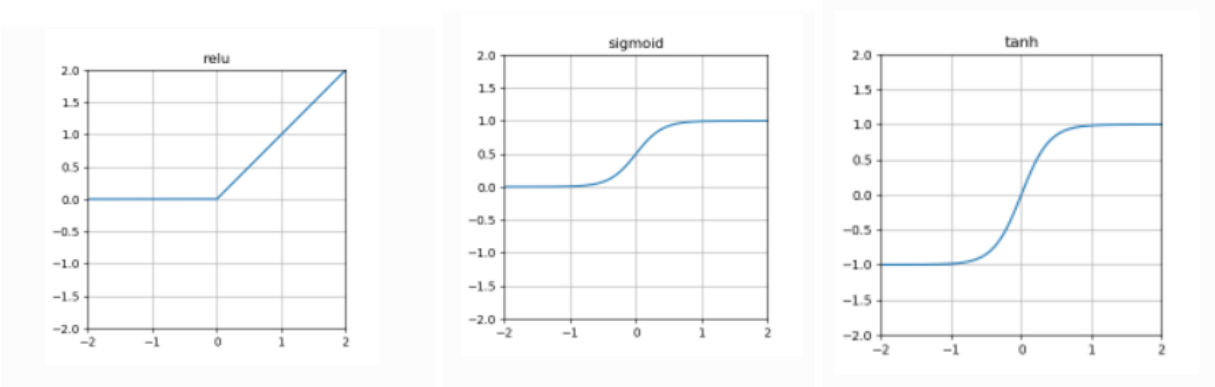

Figure 1: Common Machine Learning Cost Functions [1]

After applying the aforementioned to our robotic arm and suggesting the genetic algorithm to train 50 genomes (neural networks during a generation are called genomes), it is seen in figure 2 that the genetic algorithm will generate 50 different neural networks and allows them to train on the environment with sudden external forces Fd being introduced periodically that we have predefined

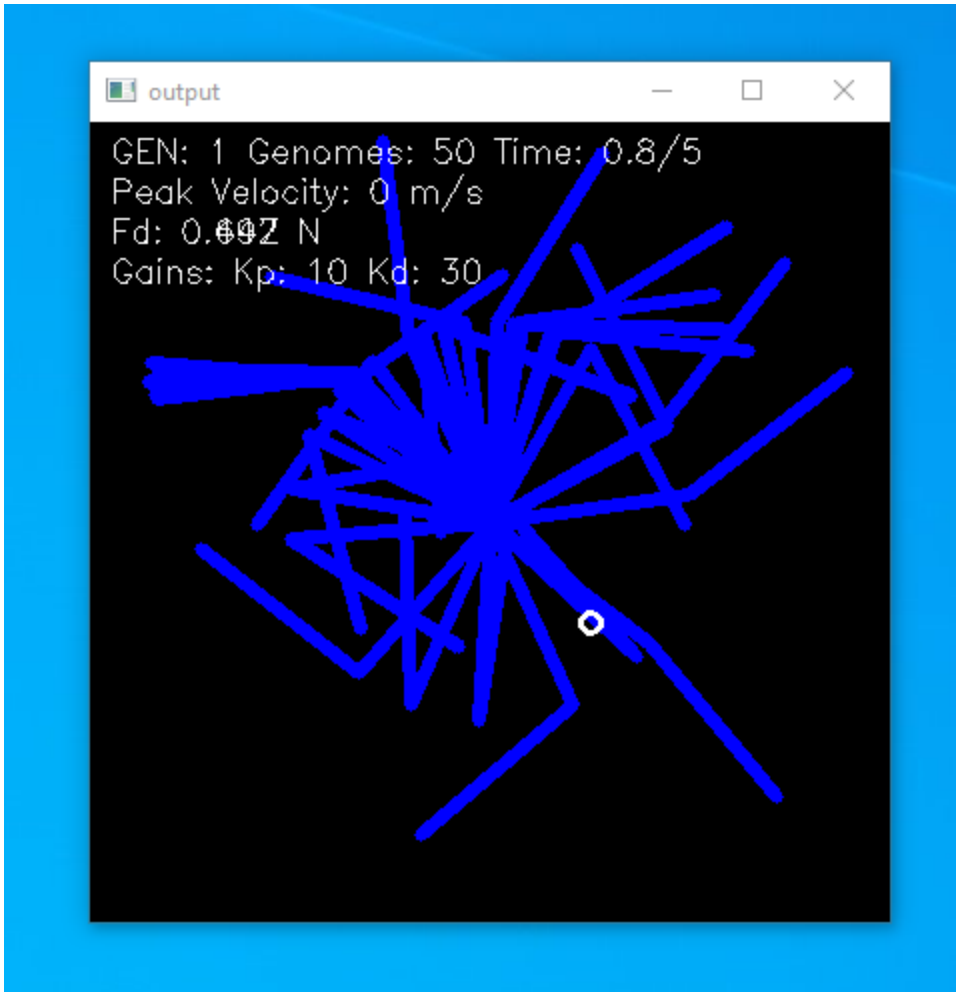

Figure 2: Genetic Algorithm Training Process

After the generation is deemed over, the genetic algorithm picks the best performing neural networks, duplicates them into another 50 neural networks and begins a brand new generation of training. Our genetic algorithm will keep on repeating the process as the neural networks improve, in our case we limited it to 100 generations.

Testing phase:

After about 30 minutes of training we pick the winning neural network and put it through a test environment where its interaction force Fd is monitored (must be kept low) and the total energy of the dynamic system is also monitored (must be constant in any physical system), as seen in figure 3, the neural network through controlling the gains of our adaptive impedance controller ensuring reduction of interaction forces with applied external forces in many predefined directions and strengths that we did not previously introduce the neural network onto during training.

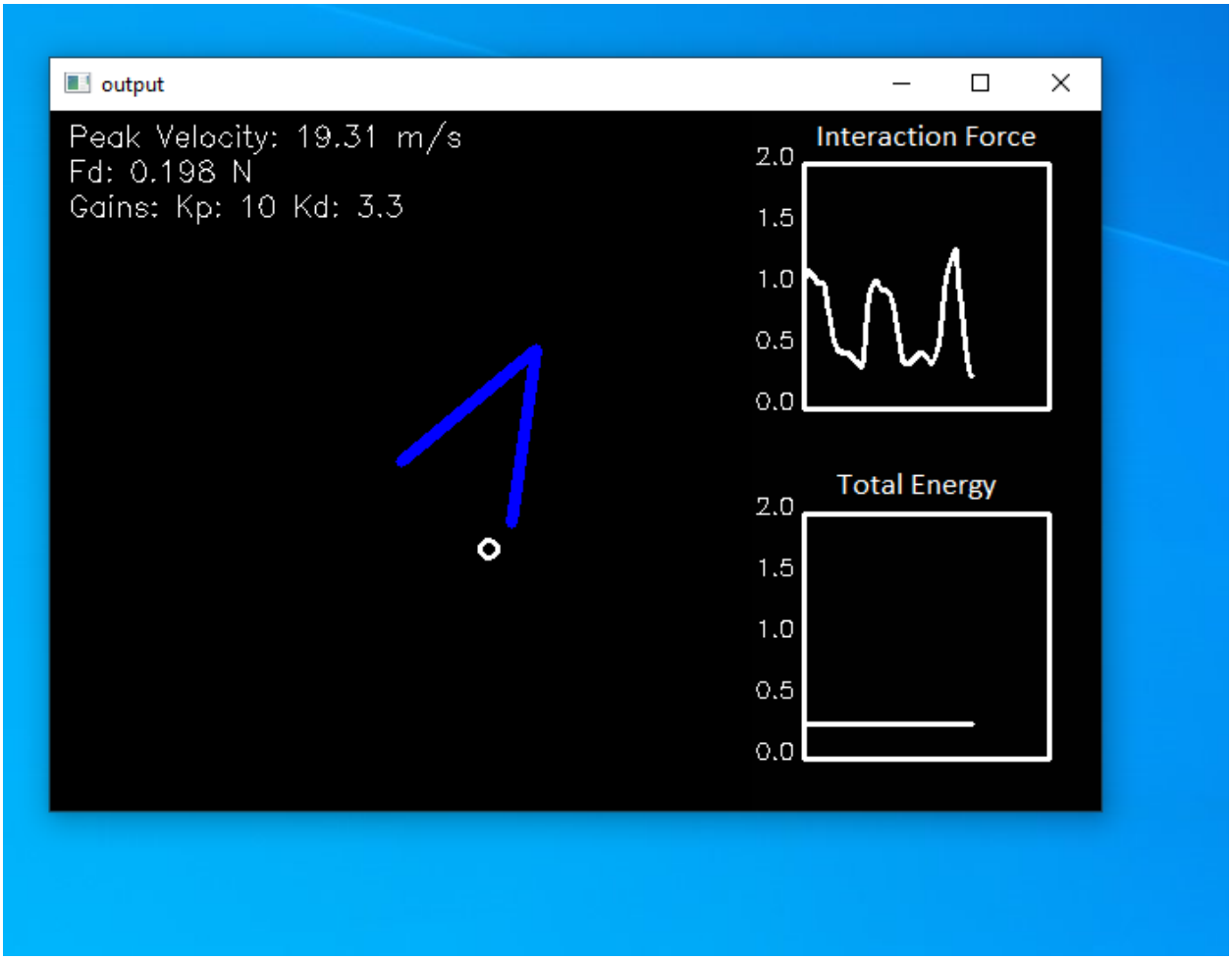

Figure 3: Testing & Monitoring of Interaction force Fd

References:

[1] Activation Functions: https://neat-python.readthedocs.io/en/latest/activation.html

Content List

Abstract

Acknowledgements

Content List

Figure Table

Abbreviations & symbols table

Introduction

Chapter 1: Introduction to Machine Learning Based Adaptive Impedance Control

- **1.1 Overview of Impedance Control**
- **1.2 Applications of Impedance Control**
- **1.3 Introduction to Adaptive Impedance Control**
- **1.4 Introduction to Machine Learning & Genetic Algorithms**

Chapter 2: Theory, Problem Description & Proposed Solution

- **2.1 Impedance Control System**
- **2.2 Challenges of Impedance Control**
- **2.3 Adaptive Impedance Control System**
- **2.4 Challenges of Adaptive Impedance Control**
- **2.5 Proposed Solution: Machine Learning & Genetic Algorithms Training**

Chapter 3: Computer Simulated Implementation (2 DOF Robotic Arm)

- **3.1 Kinematics of 2 DOF Robotic Arm**
- **3.2 Dynamic System of 2 DOF Robotic Arm**
- **3.3 Programming & Graphical Interface**
- **3.4 Adaptive Impedance Control with Machine Learning & Genetic Algorithms**

Chapter 4: Physical Implementations (Bionic hand grasping, 2 DOF Robotic Arm, ..)

- **4.1 Bionic Hand Object Grasping (Pressure Sensors)**
  - **4.1.1 3D Printing & Physical Assembly**
  - **4.1.2 Circuit Diagram of Bionic Hand**

4.1.3 Implementation of Smart Control System & Object Grasping

4.2 Bionic Hand Missing Limb Smooth Control (EMG Sensor)

4.2.1 Circuit Diagram of EMG Sensor

4.2.2 Implementation of Smart Control System & Object Grasping

4.3 Two DOF Robotic Arm

4.3.1 3D Modeling & 3D Printing & Physical Assembly

4.3.2 Kinematics Of 2 DOF Robotic Arm

4.3.3 Circuit Diagram of 2 DOF Robotic Arm

4.3.4 Implementation of Smart Control System

Chapter 5: Results And Discussion

5.1 Computer Simulation Results (2 DOF Robotic Arm)

5.1.1 Training of Neural Network using Genetic Algorithms

5.1.2 Testing of Neural Network under Never Seen Before Interaction Forces

5.1.3 Results and Discussions

5.2 Physical Implementation Results

5.2.1 Bionic Hand

5.2.2 Results and Discussion of Bionic Hand Implementation

5.2.3 2 DOF Robotic Arm

5.2.4 Results and Discussion of 2 DOF Robotic Arm Implementation

Conclusion

References

Appendices