Project Proposal
RNN Controller for Non-Linear Dynamic Systems

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Project Aim

The objective of this project is to develop a method for utilizing Recurrent Neural Networks (RNNs) to control nonlinear dynamic systems. We will begin by selecting the Van der Pol system [1], an unstable system that exhibits oscillations even with no input. Although feedback linearization can be used to convert the Van der Pol system to a linear system and apply classical linear control methods to stabilize it, this method is often considered heuristic and may not be optimal for all nonlinear dynamic systems. Therefore, we aim to propose a more general method (utilizing RNNs) that can be applied to a broader range of dynamic systems.

Implementation Details

We will start by using a simple proportional-integral-derivative (PID) controller [2] in a closed-loop control system to demonstrate the difficulty of controlling such a system. We will also attempt to introduce feedback linearization, but its necessity is unclear at this point. Then, we will train an RNN to act as a controller in the closed-loop control system as seen in Figure 1. Supervised learning will be used to train the RNN with the goal of stabilizing the Van der Pol system, meaning that the output of the system remains at a desired constant value set as the input of the closed-loop system. We will apply different set-points to the input of the closed-loop system during training and expect the output to be the same as the input set-point.

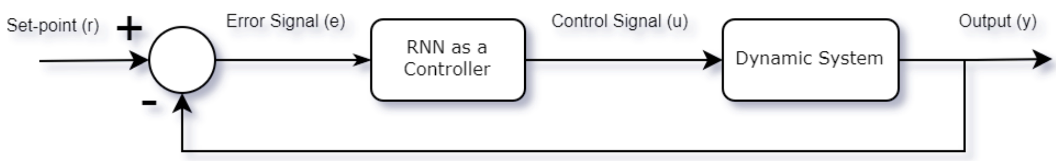

Figure 1: Block diagram of a closed-loop control system with an RNN as a controller

However, one issue in training the RNN as a controller is that we do not know the desired output of the controller, and therefore, we cannot train it in a supervised manner. One approach to overcome this challenge is using reinforcement learning and letting the RNN learn by the outcome of its generated sequence (control signal u) that is fed to the nonlinear dynamic system. Although this process may be time-consuming, it is worth exploring further.

Another approach is to use another RNN to identify the dynamic system itself. Once we have an RNN that can behave (almost) exactly like our real dynamic system, we can replace the real system with the identified RNN and consider the combination of the two RNNs as a whole (one RNN for the controller and the other RNN to replace the real dynamic system). In this configuration, we can have both the input and the desired output, allowing us to apply supervised learning to train the controller RNN. We will begin by training the second RNN to identify the real dynamic system offline. Then, we will put it in the closed-loop system and fix its weights while optimizing the weights of the first RNN (controller).

[1] https://en.wikipedia.org/wiki/Van_der_Pol_oscillator
[2] https://en.wikipedia.org/wiki/PID_controller