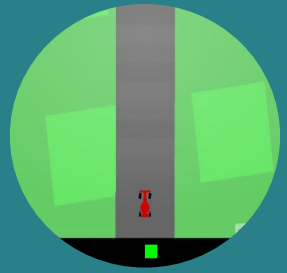


Autonomous Virtual Car Racing

Using a deep reinforcement learning model to achieve human-level control in a car racing simulator

Growth in the Car Racing Gaming Industry

- The U.S. video game market has an estimated value at around 65 billion USD [1]
- The mobile gaming market accounted for about 57% of the total worldwide gaming revenue in 2020 [2]
- The top mobile racing game (KartRider Rush+) grossed 169 million USD in revenue between April 2020 and March 2021 [3]

Programming Non-Playable Characters (NPCs)

- A common feature racing games share is the ability to race against **non-playable characters** (NPCs)
- Popular approaches to program NPCs involve explicit hard-coded algorithms: waypoint tracking and trigger detection [4]

Car Racing Game

- We use the **CarRacing-v0** environment from OpenAI Gym and the **CarRacing-v1** environment, a custom open-source environment
- Both environments:
  - Generate pixels that represent the in-game frame at each time step
  - Are based on an action space of gas (acceleration), brake (deceleration), and steering
  - At each step, the environment expects an action and outputs the next state, its associated reward, and whether or not the episode has terminated

Version 0 Environment

- Each frame is an RGB array of (96, 96, 3) pixels
- Uses a continuous action space, where the amount of acceleration, deceleration, and steering are represented by a continuous number in [0, 1]
- The reward is:
  - - 0.1 for every passing frame
  - +1000N for every track tile visited, where N is the number of tiles visited

Version 1 Environment

- The input consists of four consecutive gray-scaled frames stacked together (96, 96, 4)
- Each frame has the bottom display panel removed
- Discretized the action space to only 5 actions:
    - Left
    - Right
    - Brake
    - Accelerate
    - Do nothing

How do we define success?

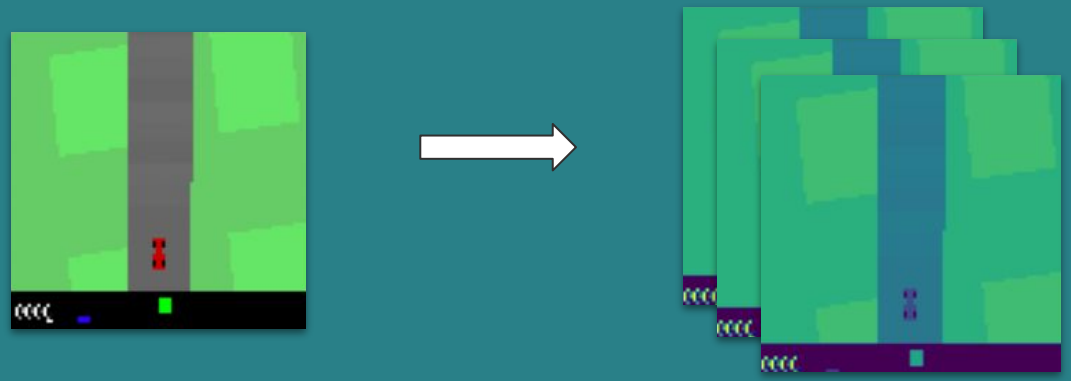
- According to OpenAI, solving the challenge requires an average reward of 900 points out of a possible 1000 over 100 consecutive trials
- Empirically, however, we may need less to surpass human performance
- Over 100 consecutive trials, I personally scored an average reward of only 598
- The OpenAI challenge benchmark and my personal human benchmark will serve as primary and secondary objectives respectively

Our Approach

1. Pre-processing
2. Modeling

Pre-processing

- Gray-scaling
- Frame-stacking
- Frame-skipping



Discretizing the Action Space

- Version 1 environment was already discretized
- We discretized Version 0 into 12 possible actions:
    - Do Nothing
    - Left
    - Right
    - Brake
    - Brake Left
    - Brake Right
    - Accelerate
    - Accelerate Left
    - Accelerate Right
    - Drift
    - Drift Left
    - Drift Right

Modeling

- Built a deep Q-learning network, which is a convolutional neural network that learns to estimate the value of taking a particular action during a given frame
- The network contained two convolutional layers and two max pooling layers, with a dense layer containing 256 hidden units
- The output units corresponded to the number of possible actions taken at any state

Generating our Dataset

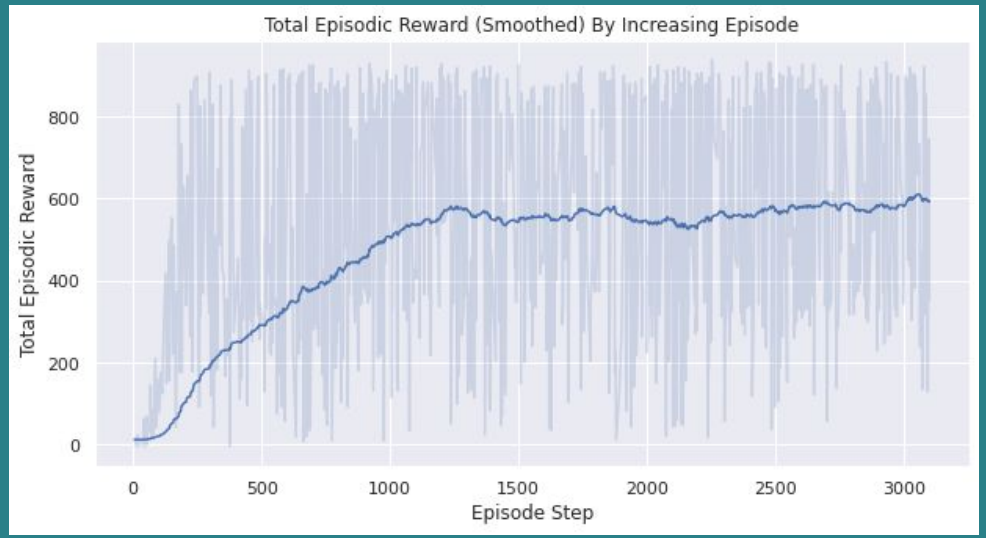
- Our neural network trained in batches of 128
- To combat inefficient learning, we reduced the number of correlated frames within a batch by using experience replay

Results

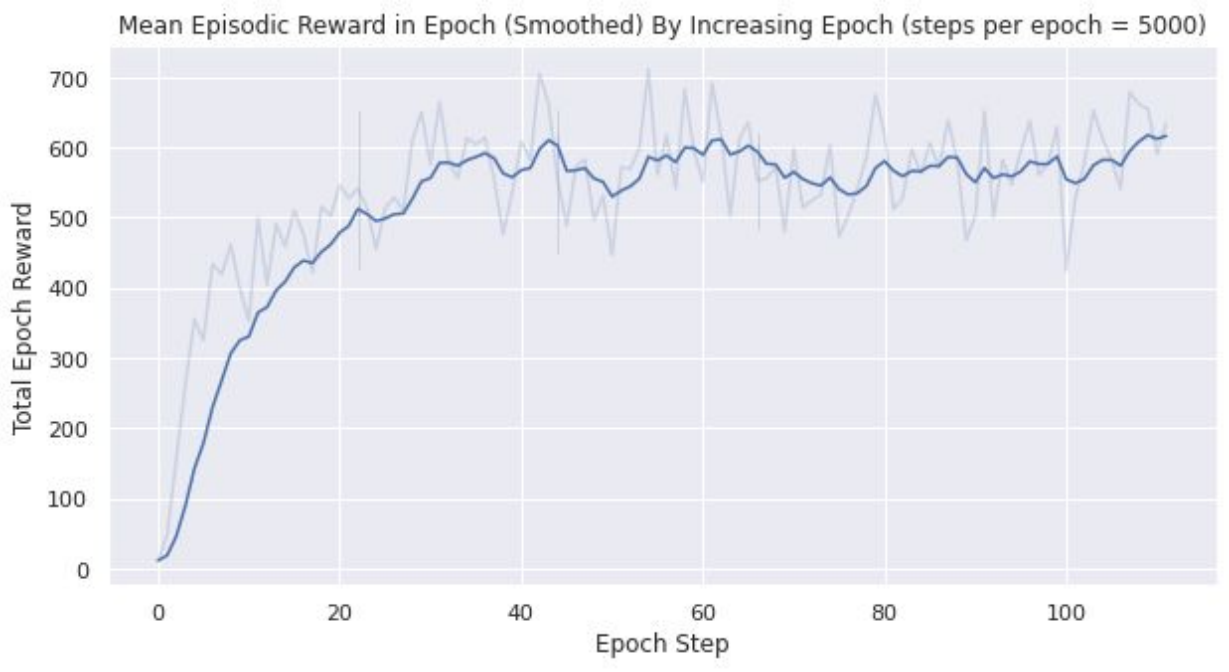
- Over 100 consecutive trials, the V1 agent scored an average of 410 out of 1000 possible points
- Over 100 consecutive trials, the V0 agent scored an average reward of 820 out of 1000 possible points, surpassing the sample human performance

Results

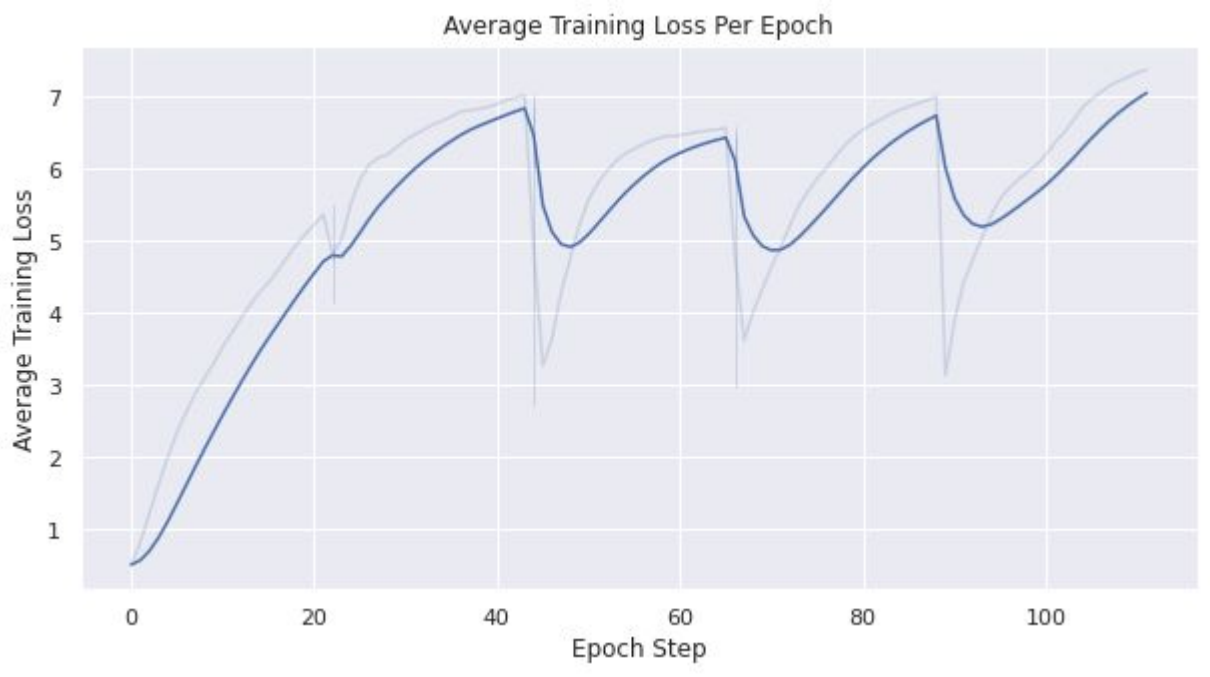
- Over 100 consecutive trials, the agent scored an average reward of 820 out of 1000 possible points, surpassing the sample human performance



Mean Episodic Reward in Epoch



Training Loss



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