

Fido: A Universal Robot Control System using Reinforcement Learning with Limited Feedback

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Abstract

A robot control system was developed that could be taught tasks through reinforcement learning. The system, nicknamed “Fido”, was designed to be universal regardless of the specific hardware inputs and outputs and does not need to be modified for the task at hand. In addition, Fido was built to learn with limited feedback, allowing humans to train Fido in a reasonable time frame. This was achieved through the training of artificial neural networks with a wire-fitted moving least squares interpolator following the Q -learning reinforcement algorithm and an action selection policy that utilizes a Boltzmann distribution of probability. Initially robots of different drive systems were simulated with sensors to test functionality. Next a small robot using the Intel Edison compute module, dubbed “Thing One,” was constructed for physical testing. The robot was successfully trained to do a variety of tasks with limited feedback, such as staying put and driving to a point. A second hardware implementation, titled “Thing Two,” was implemented using the \$5 Raspberry Pi Zero. Thing Two successfully performed even more advanced tasks with its complex holonomic drive system, such as line following and playing fetch. Fido successfully converged on all these tasks in very few reward iterations while maintaining impressively low latency, demonstrating its potential as a comprehensive robot control system.

New Hardware Implementation

Between the preliminary and final rounds of NYCSEF, we implemented a new robot to run the Fido control system, nicknamed “Thing Two.” Thing Two has three 90-degree Swedish wheels at 120° angles, allowing it to control all the robot’s degrees of freedom (otherwise known as a holonomic drive system).

Additional Results

For this round of NYCSEF, we were also able to perform additional testing, mainly due to the development of our new hardware implementation, “Thing Two”. The drive straight task challenged Fido to master the advanced kinematics of its holonomic drive system; the robot was trained to move in a straight line. In the line following task, Thing Two was trained to use its drive system and an array of infrared photo-sensors to learn to follow a line. Thing Two was also trained to use its ZX gesture sensor to learn to follow a ball, or play fetch. In the limp task, first a trained line following model was loaded. Next, the wires to one of Thing Two’s wheels were removed, and Fido was retrained to follow a line

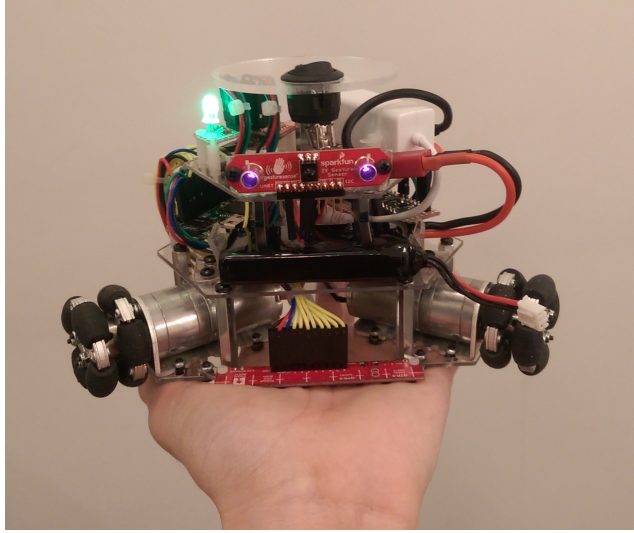


Figure 1: Fido’s Second Hardware Implementation, or “Thing Two”

using only his two remaining wheels. This task demonstrated the applications of Fido over standard procedurally-programmed robot control systems; rather than having to be fully reprogrammed, Fido can be retrained to adapt to unexpected circumstances in the field. This task also demonstrates Fido’s retrainability and universality, as it was both able to be retrained and adapt to a new drive system.

Task	Learning Iterations	Action Selection (ms)	Training Time (ms)
Drive Straight	6	0.	6
Line Following	14	21	110
Fetch	17	1	11
Limping Line Following	6	20	37

Table 1: Number of Learning Iterations, Action Selection Time, and Training Time Per Iteration for Thing Two Tasks (20 Trials)

In addition to the additional tasks implemented on Thing Two, a further test was run on Fido’s simulator. This test evaluated Fido’s ability to disregard irrelevant and noisy sensor data unrelated to the task at hand. For a line following test, in addition to a line sensor Fido was given a light sensor as an input, which was set to random values.

Task	Learning Iterations	Action Selection (ms)	Training Time (ms)
Noisy Line Following	10	1.	12

Table 2: Number of Learning Iterations, Action Selection Time, and Training Time Per Iteration for Additional Simulator Tasks (400 Trials)