Safe Learning Documentation

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1 Introduction

This is the documentation of the Python implementation of the Safe Learning algorithm and its related simulations based on [1]. The code can be found in the following online GitHub repository: `https://github.com/lina-robotics-lab/SafeLearning`.

See Section 2 for a mathematical description about the system model we used in the simulations.

See Section 3 for a quick guide to run the simulation.

Section 4 contains detailed documentations for each component of the implementation.

2 System Model

We consider a dampened spring-mass system in the simulation. The system contains a mass with weight $m > 0$ attached to a spring with stiffness constant $k > 0$. The mass is restricted to move along a one-dimensional surface perpendicular to the gravity direction, and we assume no friction between the mass and the surface. We can apply an external force u on the mass along the trajectory of its movement to control its state.

Let $x \in \mathbb{R}$ be the location of the mass, the system equation in continuous time can be defined as

$$\ddot{x} = (-kx - \lambda \dot{x} + u)/m \tag{1}$$

In the implementation, we approximate (1) using a discrete-time system defined by

$$s_t := \begin{bmatrix} x_t \\ v_t \end{bmatrix} = \left(\begin{bmatrix} 0 & \Delta \\ -\frac{k\Delta}{m} & -\frac{\lambda\Delta}{m} \end{bmatrix} + I \right) \begin{bmatrix} x_{t-1} \\ v_{t-1} \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{\Delta}{m} \end{bmatrix} u_{t-1} \tag{2}$$

where $\Delta > 0$ is a small constant representing the sampling time interval.

3 How to run the simulations

Step 1: clone the git repository to a local folder by

```
git clone https://github.com/lina-robotics-lab/SafeLearning
```

Step 2: Install the Python packages required by the simulation. Especially, jupyterlab, matplotlib, scipy, and cvxpy.

I recommend installing the Python environment manager called *conda* `https://docs.conda.io/en/latest/miniconda.html`, and follow `https://docs.conda.io/projects/conda/en/latest/user-guide/tasks/manage-environments.html` to create a new Python environment. This ensures the new packages do not interfere with the original Python on your computer which serves crucial purposes such as rendering your desktop and windows.

A typical flow of operations after installing *conda* is

```
conda create -n SafeLearningEnv python=3.9 scipy jupyterlab matplotlib
conda activate SafeLearningEnv
pip install cvxpy
```

Step 3: Ensure the Python environment we created in Step 2 in command prompt by

```
conda activte SafeLearningEnv
```

Navigate to the SafeLearning folder in command prompt. Then start the jupyter lab by running

```
jupyter lab
```

The default browser of your computer should pop up and show a tab loading the jupyter lab. Eventually you will see something like the screenshot in Figure 1.

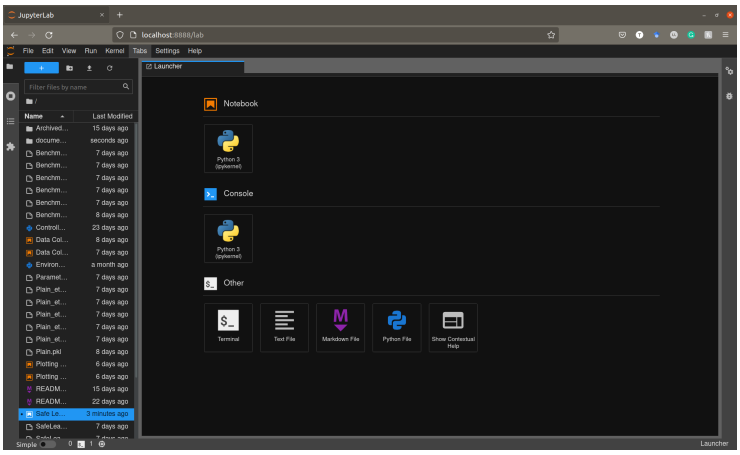

Figure 1

Step 4: in the jupyter lab window, double click to open the *[Safe Learning Simulation.ipynb]* notebook.

Press *Esc* to enter command mode.

Press *Ctrl+a* to select all cells.

Finally, press *Ctrl + enter* to run the entire notebook from start to end.

The Python notebook works similarly as the live scripts/run by section utility in Matlab. Watch this video for a 30-min beginner's tutorial on Python notebooks:`https://www.youtube.com/watch?v=HW29067qVWk`.

4 Detailed Documentations

References

[1] Y. Li, S. Das, J. Shamma, and N. Li, "Safe adaptive learning-based control for constrained linear quadratic regulators with regret guarantees," *arXiv preprint arXiv:2111.00411*, 2021.