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Value Iteration for Learning Concurrently Executable Robotic Control Tasks

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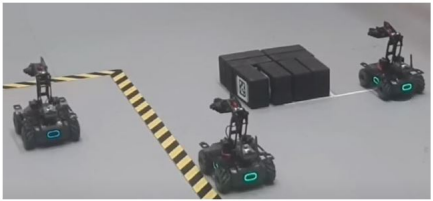
Motivation



Modern robots are required to do complex tasks and possibly multiple at the same time.

- Let's use RL to learn several control tasks for a robotic system to execute.
  - RL lets us generalize to possibly complex control tasks.
- Let's combine and execute each of these tasks together.
  - Preferably in a way that lets us swap out tasks and/or reorder priorities.
- How do we know that tasks will not interfere with each other?

Assumptions

- Assume that our robotic system is control-affine:

$$\dot{x} = f(x) + g(x)u,\ x \in \mathbb{R}^n,\ u \in \mathbb{R}^p$$

- Assume that each RL task we learn is encoded with a “cost-to-go"/value function of the form:

$$J_i(x) \approx \min_{u(\cdot)} \int_t^\infty q_i(x(\tau))) + \|u(\tau)\|^2 d\tau,\ q_i(x) \geq 0$$

Key Related Works

Related Work - Combining Learned Tasks Using a Min-Norm Controller

- Treat learned value functions as Control Lyapunov Functions
- Make progress on each task using constrained optimization problem

$$
\begin{aligned}
\min_{u \in \mathcal{U}, \delta \in \mathbb{R}^N} \quad & \|u\|^2 + \kappa \|\delta\|^2 \\
\text{s.t.} \quad & L_f J_1(x) + L_g J_1(x) u \leq -\sigma_1(x) + \delta_1 \\
& \vdots \\
& L_f J_N(x) + L_g J_N(x) u \leq -\sigma_N(x) + \delta_N \\
& K\delta \geq 0
\end{aligned}
$$

Note that: $L_f J_i(x) = \frac{\partial J_i}{\partial x} f(x)$, $L_g J_i(x) = \frac{\partial J_i}{\partial x} g(x)$.

[1] G. Notomista, "A Constrained-Optimization Approach to the Execution of Prioritized Stacks of Learned Multi-robot Tasks," in Distributed Autonomous Robotic Systems, 2024, pp. 479–493

Math Expressions

Integrals and Other Expressions

$$\iint_{\partial\Omega} f(x)\mathrm{d}x \in \mathbb{C} \tag{1}$$

$$E = mc^2 \tag{2}$$

$$F = ma \tag{3}$$

m Mass
c Speed of light

Theorem

The following statement is correct

$$\frac{\partial f(\vec{x})}{\partial x_i} = \sum_{l=1}^{L} \cos\left(l\frac{2\pi}{L} + 0\right) \tag{4}$$

Elements

Typography

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The theme provides sensible defaults to
\emph{emphasize} text, \alert{accent} parts
or show \textbf{bold} results.
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becomes

The theme provides sensible defaults to *emphasize* text, **accent** parts or show **bold** results.

Font feature test

- Regular
- *Italic*
- Small Caps
- **Bold**
- ***Bold Italic***
- **Bold Small Caps**
- `Monospace`
- *`Monospace Italic`*
- **`Monospace Bold`**
- ***`Monospace Bold Italic`***

Lists

Items

- Milk
- Eggs
- Potatoes

Enumerations

1. First,
2. Second and
3. Last.

Descriptions

PowerPoint Meeh.

Beamer Yeeeha.

Tables

Table 1: Largest cities in the world (source: Wikipedia)

City	Population
Mexico City	20,116,842
Shanghai	19,210,000
Peking	15,796,450
Istanbul	14,160,467

Blocks

Three different block environments are pre-defined and may be styled with an optional background color.

Default

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Alert

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Example

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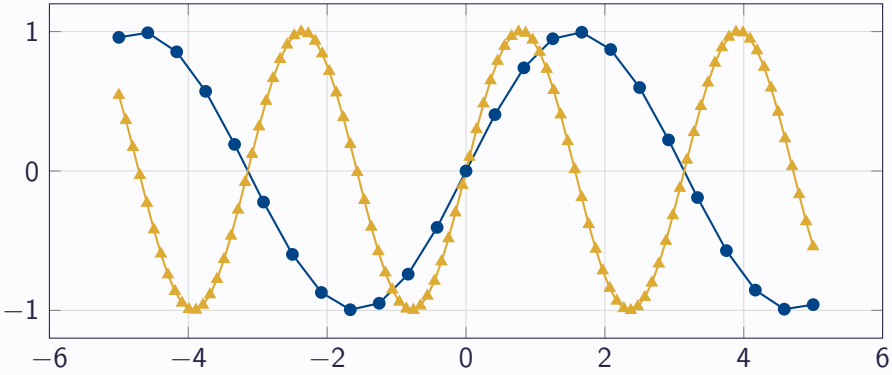
Line plots



Standout Frame!

Backup slides

Sometimes, it is useful to add slides at the end of your presentation to refer to during audience questions.

The best way to do this is to include the `appendixnumberbeamer` package in your preamble and call `\appendix` before your backup slides.

The theme will automatically turn off slide numbering and progress bars for slides in the appendix.