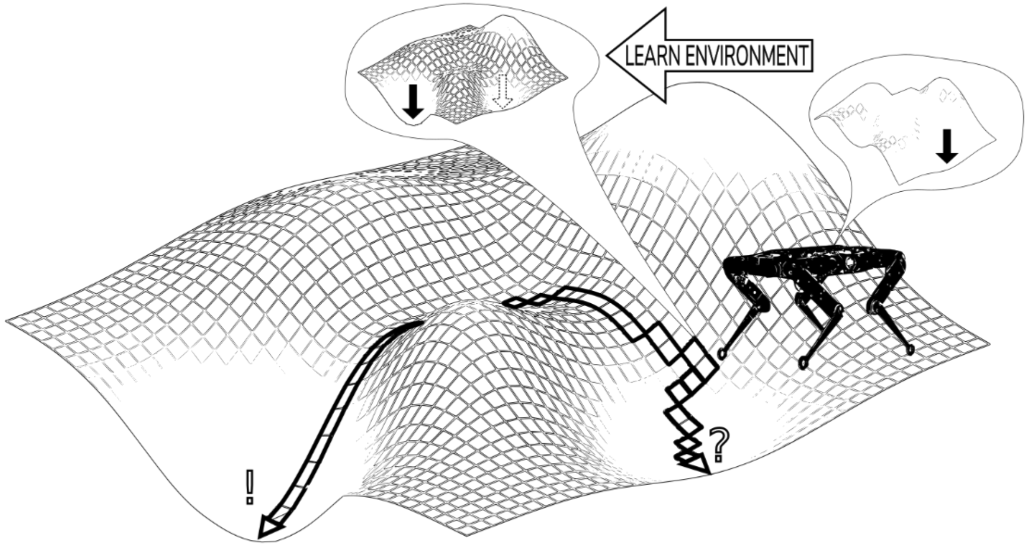
AI in dynamic action



Seminar 1: RL terminology

Skolkovo Institute of Science and Technology

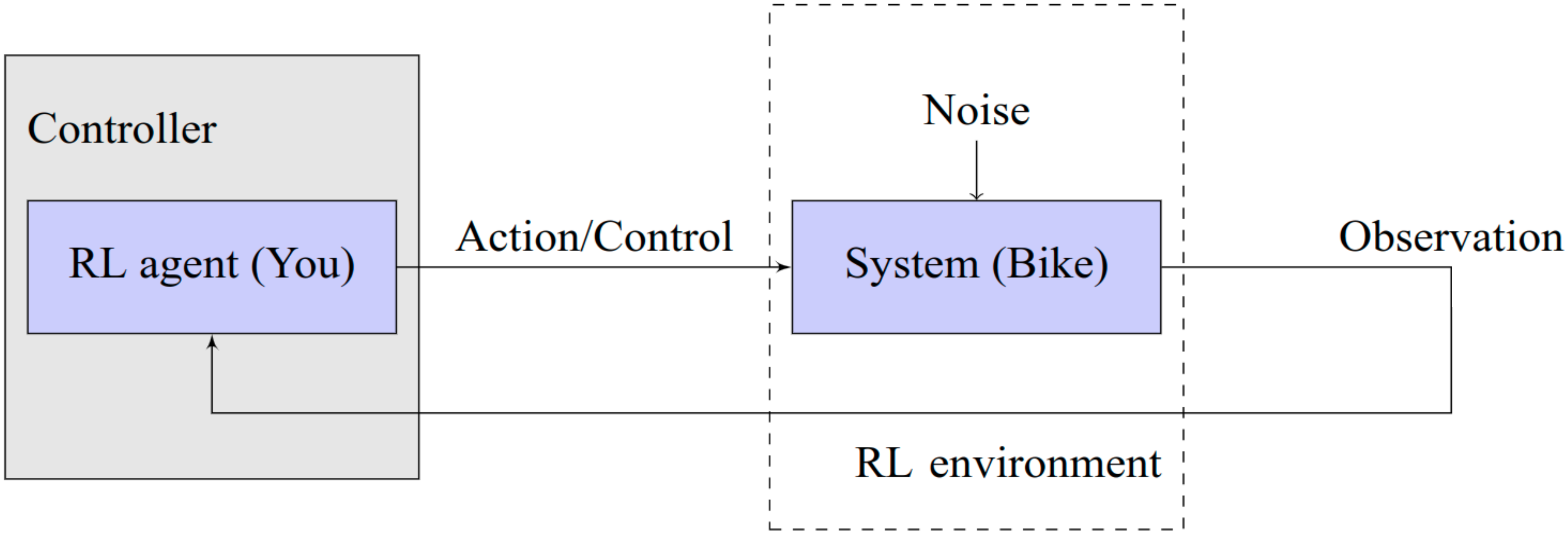
RL Agent & RL Environment vs. Controller & Control-system

$$\textbf{RL Agent} \overset{?}{=} \textbf{Controller}$$

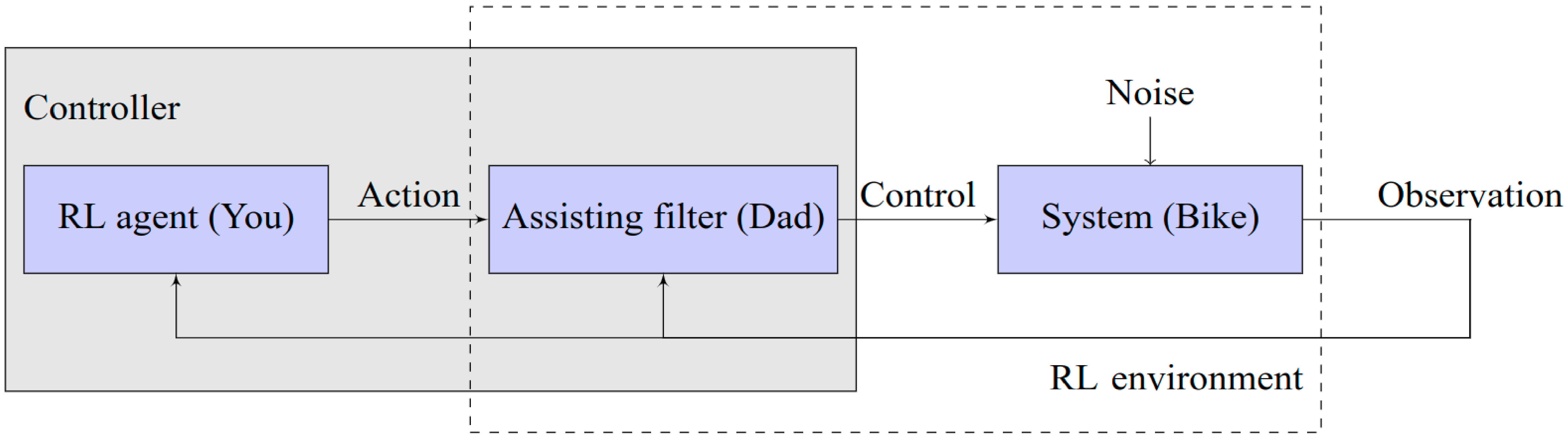
$$\textbf{RL Environment} \overset{?}{=} \textbf{Control-system}$$

$$\textbf{Action} \overset{?}{=} \textbf{Control input}$$

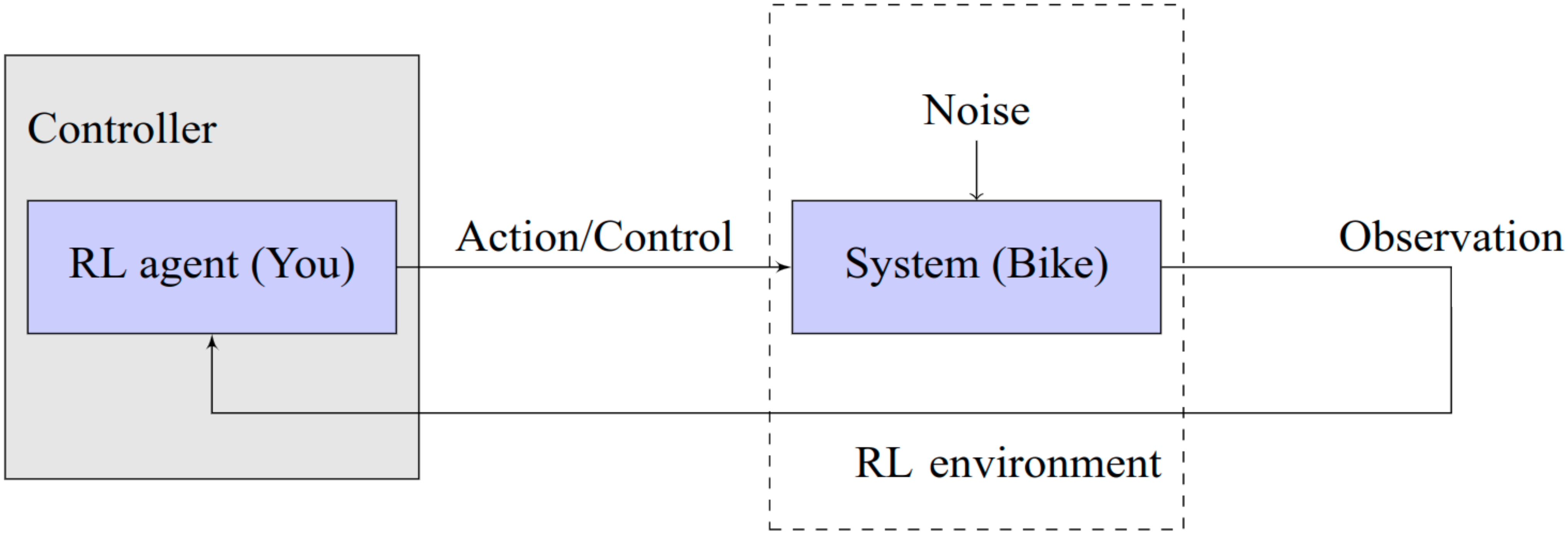
RL Agent & RL Environment vs. Controller & Control-system



RL Agent & RL Environment vs. Controller & Control-system



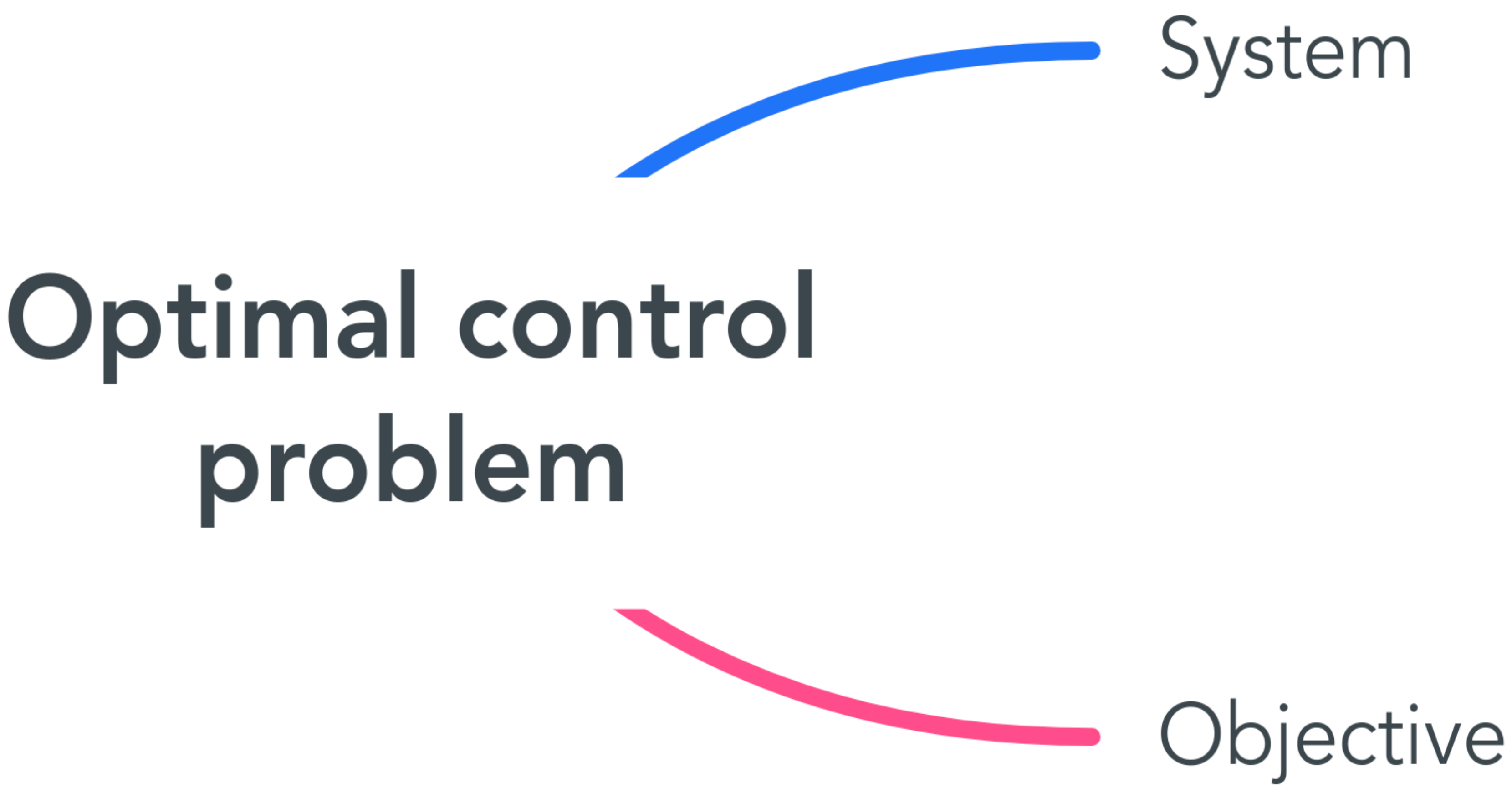
RL Agent & RL Environment vs. Controller & Control-system



Please, split into groups of three.

Problems and methods

Problems related terminology



Discrete time vs. Continuous time

System

Discrete time

$$T := \mathbb{Z}$$

Continuous time

$$T := \mathbb{R}$$

Discrete time vs. Continuous time

$$f : \mathbb{R}^n \times \mathbb{U} \to \mathbb{R}^n$$

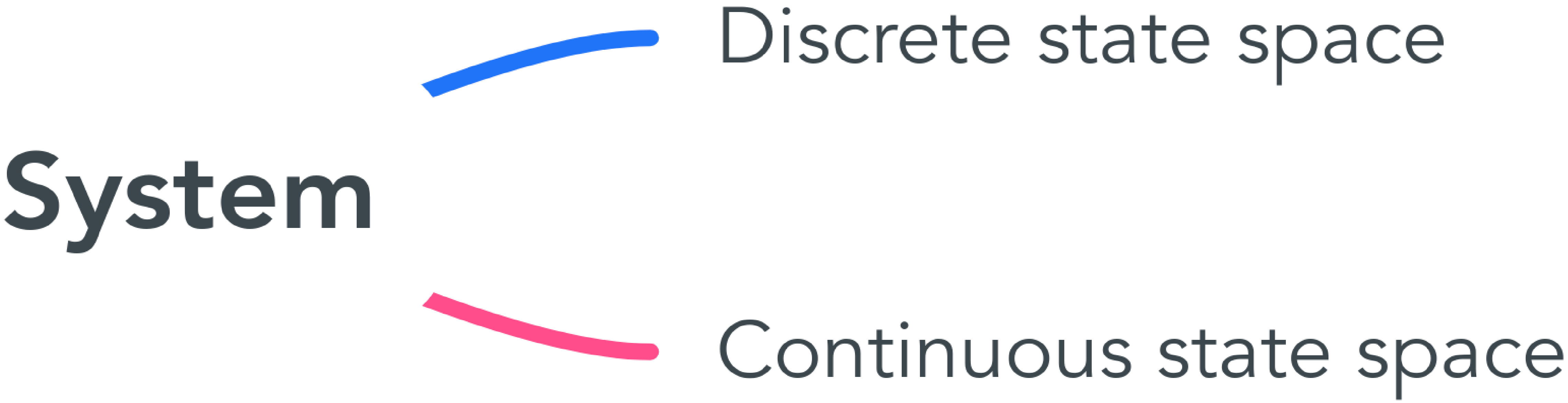
State dynamics function

Continuous: $$\frac{\partial}{\partial t} x(t) = f(x(t), u(t))$$

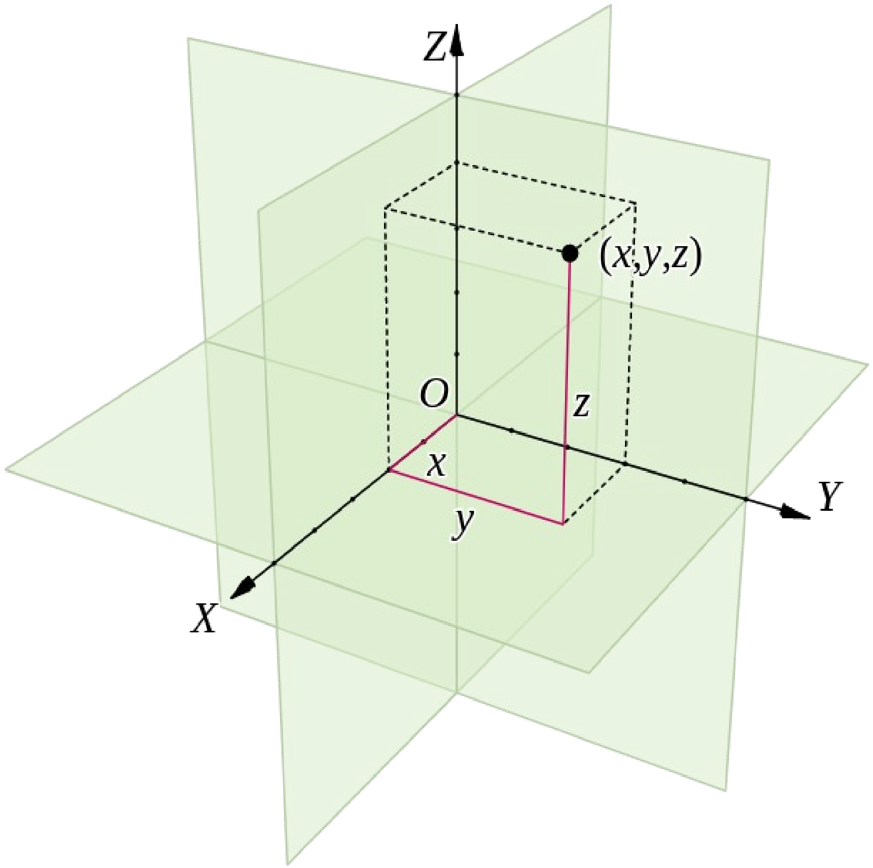
Discrete: $$x_{t+1} = f(x_t, u_t)$$

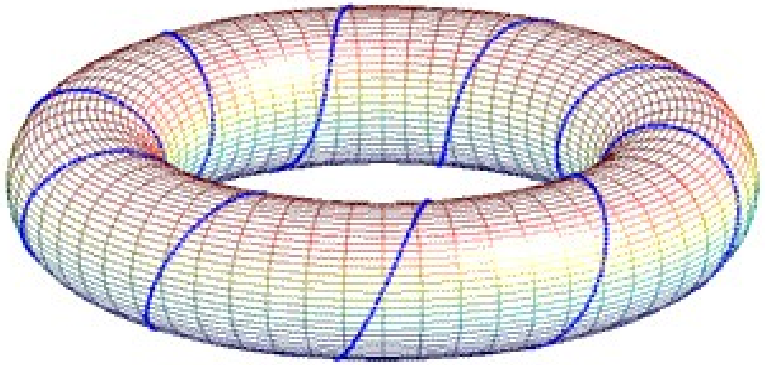
State transition function

Discrete state space vs. Continuous state space



Continuous state space



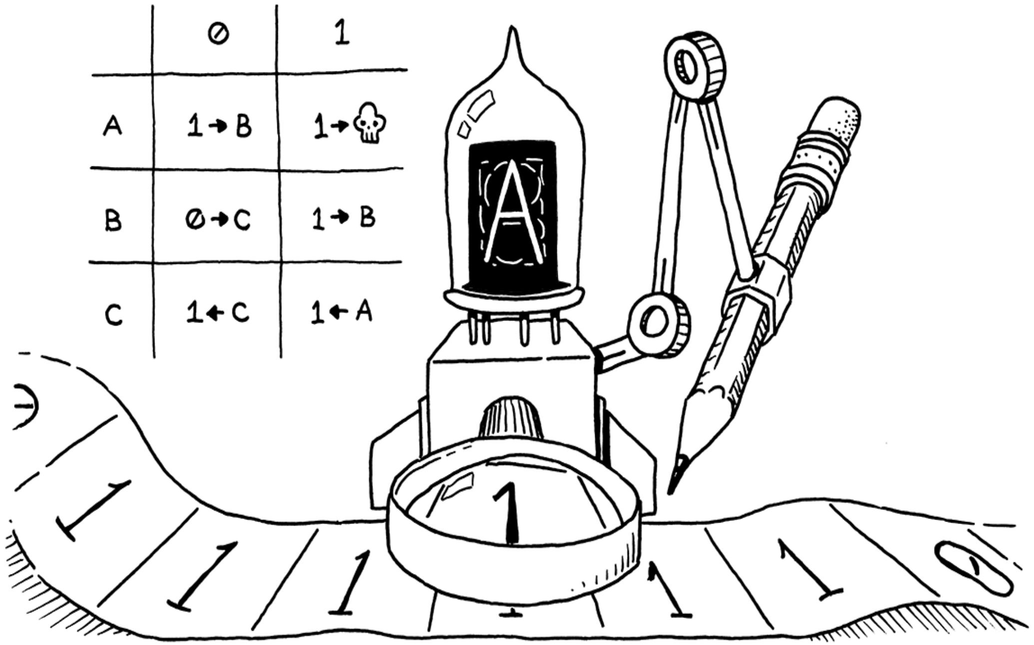


Discrete state space

?

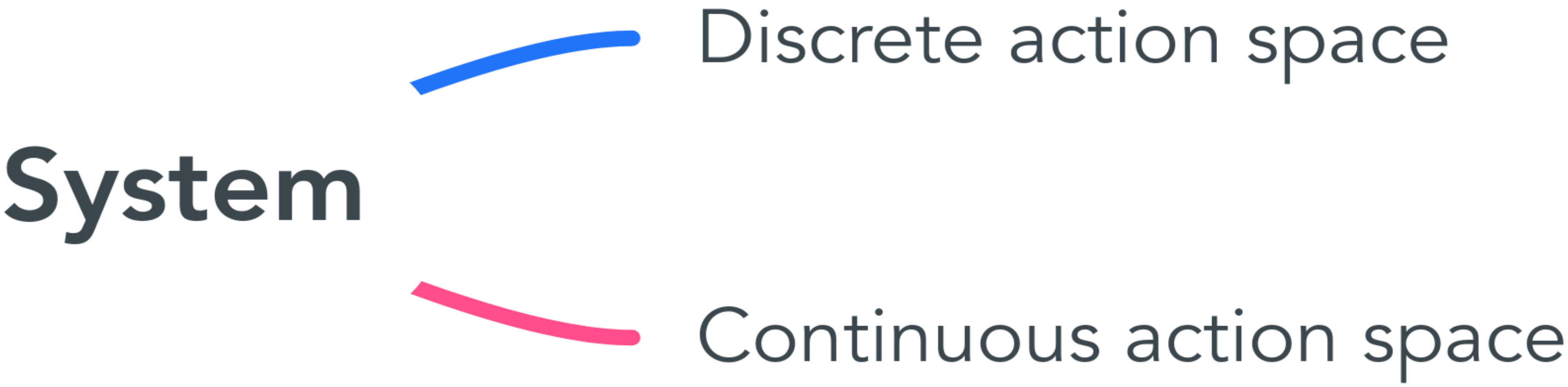
?

Discrete state space



$$x_{t+1} = f(x_t, u_t),$$
$$f : \mathbb{Z} \times \mathbb{U} \to \mathbb{Z}$$

Discrete action space vs. Continuous action space



Discrete action space vs. Continuous action space

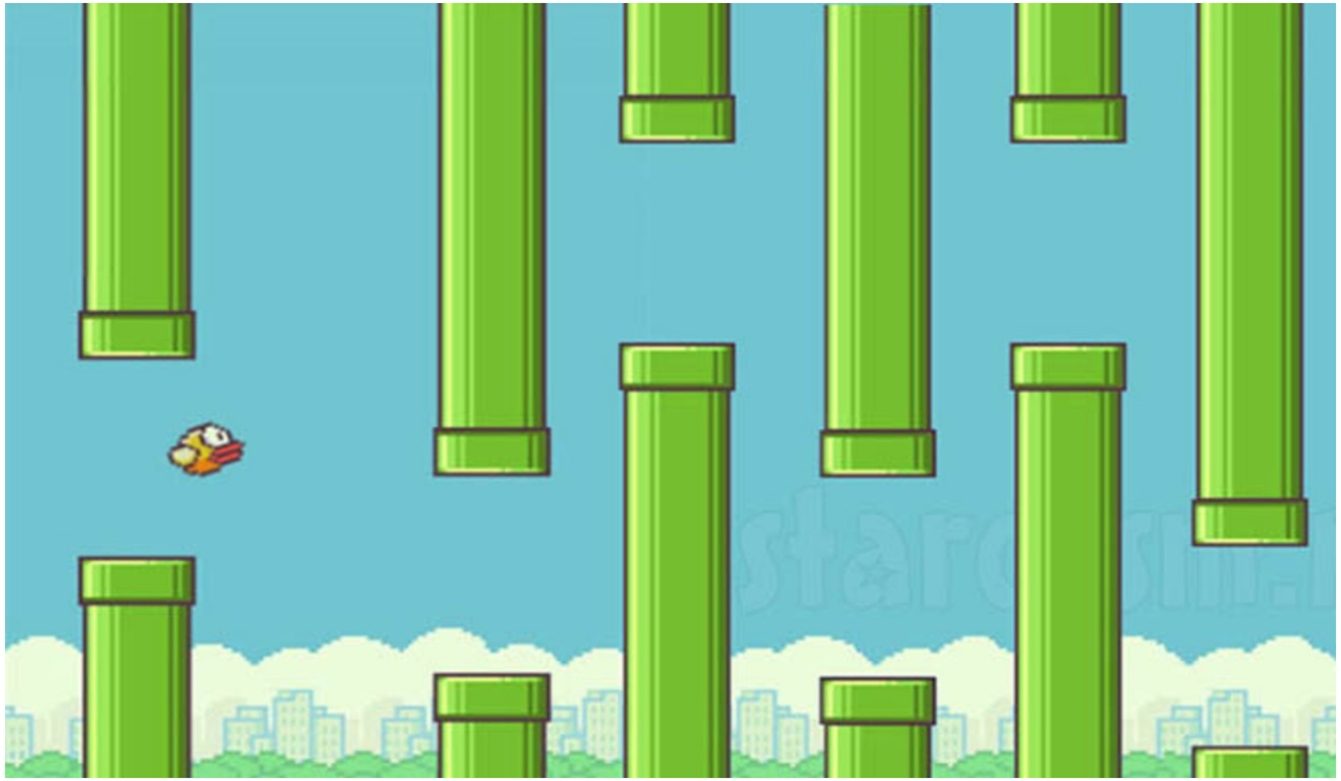
Continuous

Discrete

Discrete action space vs. Continuous action space

$$\text{Action space} \;\approx\; \text{Control set } (\mathbb{U})$$

Discrete action space with continuous time and state space



Continuous action space with discrete time and state space

?

Continuous action space with discrete time and state space

$$x_{t+1} = f(x_t, u_t) + \lceil \sigma(x_t, u_t)\xi_t \rceil,$$

$$f : \mathbb{Z} \times \mathbb{U} \to \mathbb{Z},$$
$$\sigma : \mathbb{Z} \times \mathbb{U} \to \mathbb{R},$$
$$\xi_t \sim \mathcal{N}(0, 1)$$

Stochastic vs. Deterministic

Stochastic Systems

?

Stochastic systems

Pretty much anything

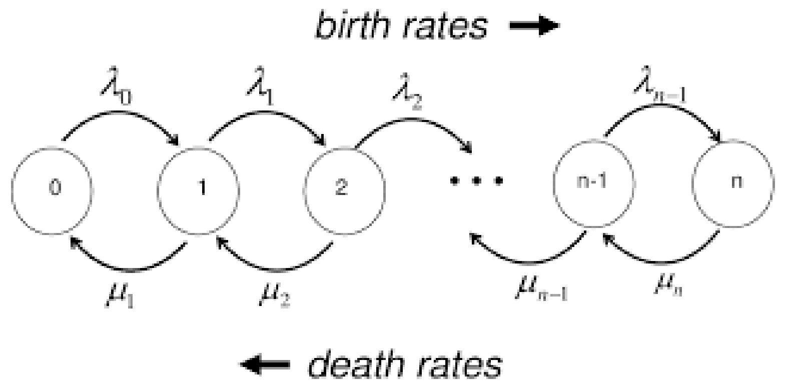
Stochastic systems

Continuous state space

Discrete state space

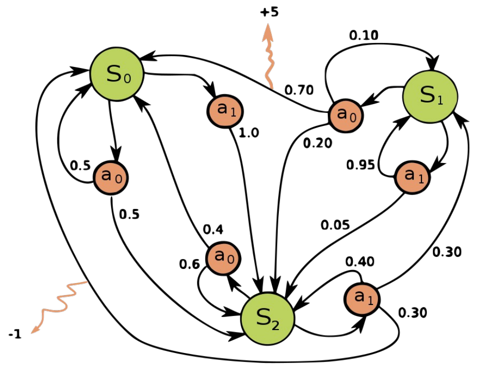
Continuous time

$$\mathrm{d}X_t = f(X_t, U_t)\,\mathrm{d}t + \sigma(X_t, U_t)\,\mathrm{d}W_t,$$
$$W_t \; - \; \text{semimartingale.}$$



Discrete time

$$x_{t+1} \sim \mathcal{F}(x_t, u_t)$$



Full information vs. Partial information

Full information vs. Partial information

$$\textbf{Observation} \stackrel{?}{=} \textbf{State}$$

Full information vs. Partial information

Full information

Observation = State

Partial information

Observation ≠ State

Partial information examples

$\rho(\cdot)$ – feedback policy.

Full information

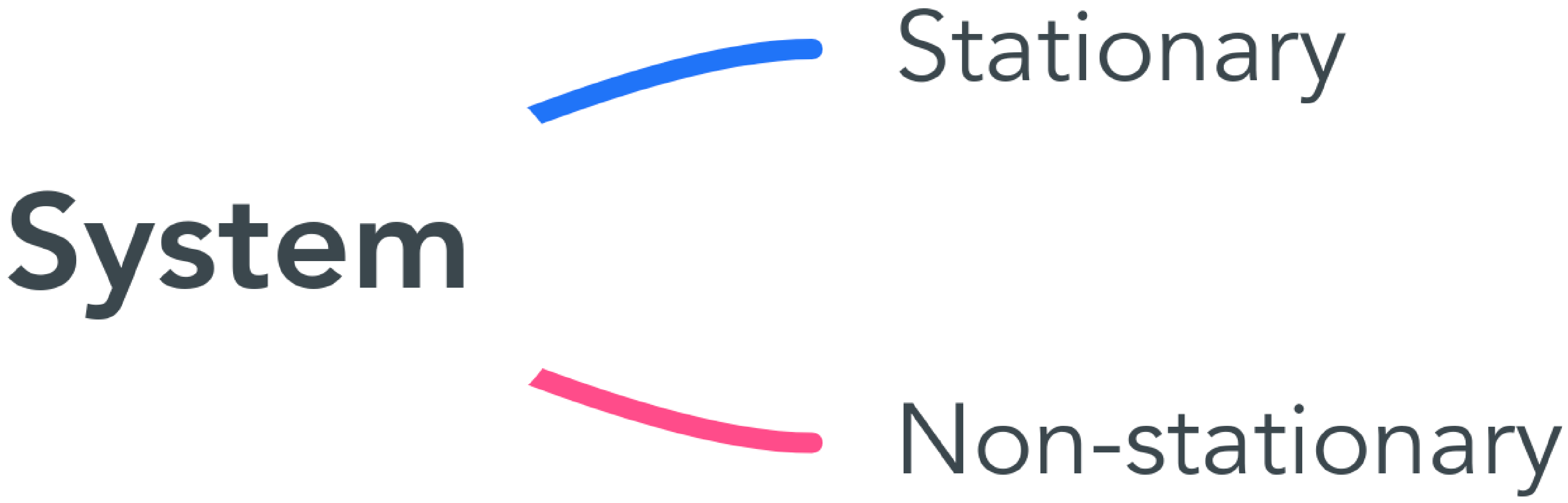
$$u(t) := \rho(x(t))$$

Partial information

$$u(t) := \rho(g(x(t)))$$

$$u(t) := \rho(x(t) + \xi_t), \ \xi \sim \mathcal{N}(\mu, \sigma^2)$$

Stationary vs. Non-stationary



Stationary vs. Non-stationary

Non-stationary

$$x_{t+1} := f(x_t, u_t, t)$$

Stationary

$$x_{t+1} = f(x_t, u_t)$$

Non-stationary --> stationary

$$x_{t+1} := f(x_t, u_t, t) \longrightarrow \begin{aligned} x_{t+1} &= f(x_t, u_t, y_t) \\ y_{t+1} &= y_t + 1 \end{aligned}$$

Example of a non-stationary system

?

Example of a non-stationary system

Cost vs. Reward

Cost vs. Reward

Cost $\longrightarrow$ Minimize

Reward $\longrightarrow$ Maximize

Finite horizon vs. Infinite horizon

Finite horizon vs. Infinite horizon

Finite-horizon

You optimize the objective over a finite time frame.

Infinite-horizon

You optimize the objective over an infinite time frame. (As if your RL agent were to run for all eternity)

Running vs. Terminal

Running vs. Terminal

$J(\cdot,\cdot)$ – total objective.

Running objective

$$J(x(\cdot), u(\cdot)) := \int_{t_1}^{t_2} r(x(t), u(t))\, \mathrm{d}t + T(x(t_2))$$

$$J(x_\cdot, u_\cdot) := \sum_{i=t_1}^{t_2} r(x_i, u_i) + T(x_{t_2})$$

Terminal objective

Terminal objective

?

Model-based vs. Model-free

Model-based vs. Model-free

$$\dot{x} = f(x, u)$$

Model-based

Aware of the system's **dynamics**. Able to predict immediate outcomes of its own actions.
Learns by numerically approximating the optimal policy.

Model-free

Relies solely on it's own **experience**.
Learns by associating rewards with states and actions through statistical modeling.

Offline vs. Online

Offline vs. Online

Offline

Learning occurs **before** the agent is deployed.

Online

Learning occurs **while** the agent is deployed.

Q&A