Meta-Reinforcement Learning and Causality for Multi-tasking in Robots with Redundant Kinematics

1st Year Update

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Focus

Meta-Reinforcement Learning and Causality for Multi-tasking in Robots with Redundant Kinematics

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Translation: Explore different learning methodologies to create intelligent agents that can control robots in difficult tasks

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Motivation

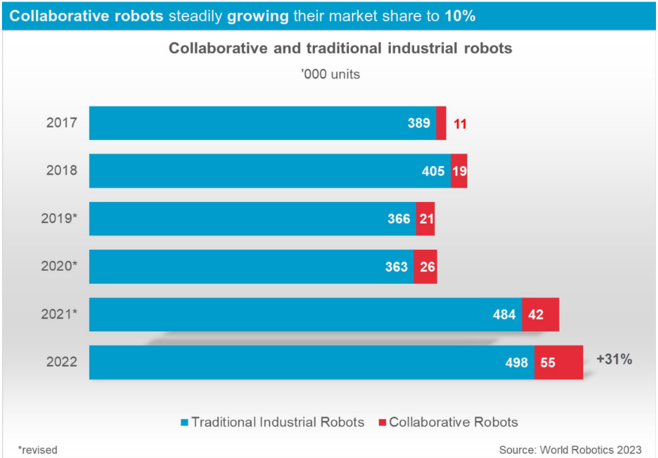
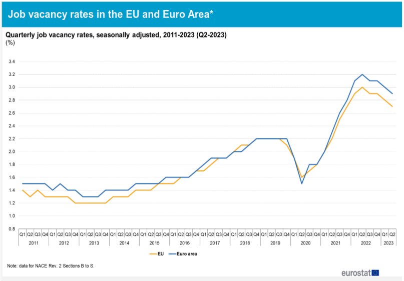


Figure: Collaborative and traditional industrial robots' growth[1]

Motivation



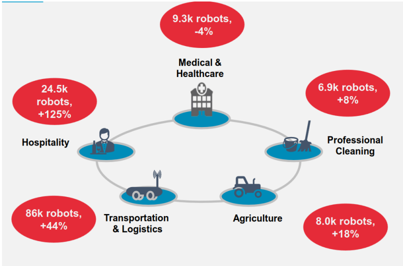


Figure: Job vacancy and service robots' growth[1]

Job vacancy is rising and the field of service robots is growing in response

[1]Source: World Robotics Report 2023 - Press Conference

Motivation

Cobots and Service Robots interact in more complex and uncontrolled environments, ...

Motivation

Cobots and Service Robots interact in more complex and uncontrolled environments, ...
... therefore, they need to be more **flexible and adaptable** to different tasks.

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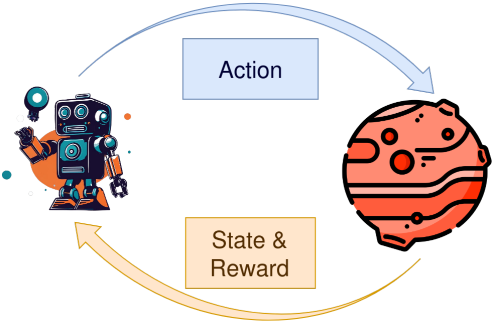
Reinforcement Learning



Learns to accomplish a goal by **interacting** with an environment, receiving rewards and penalties.

RL vs Traditional Control

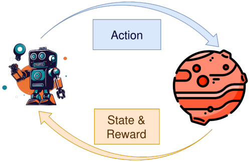


Figure: Reinforcement Learning Cycle

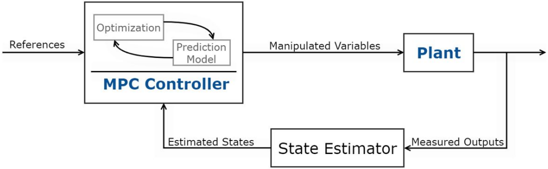


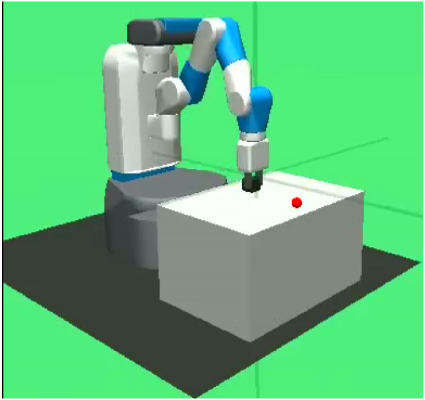
Figure: Model Predictive Control Cycle

Just to mention that there are other methods to control robots, such as MDP, but they are not as flexible as RL.

RL vs Traditional Control

[2] Source: Robotics Systems Lab: Legged Robotics at ETH Zurich

RL vs Traditional Control



RL vs Optimal Control

- Traditional Control: Robust and predictable, but not scalable.
- Reinforcement Learning: Scalable and flexible, but not robust.

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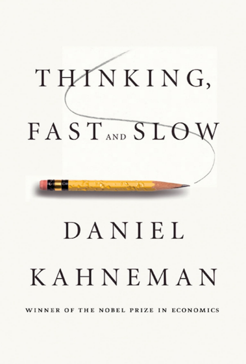
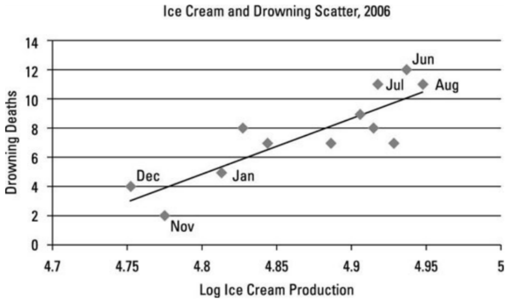
Intuition



- **Fast Thinking**: Correlation, pattern recognition, subconscious, ...
- **Slow Thinking**: Logical (causal), calculating, conscious, ...

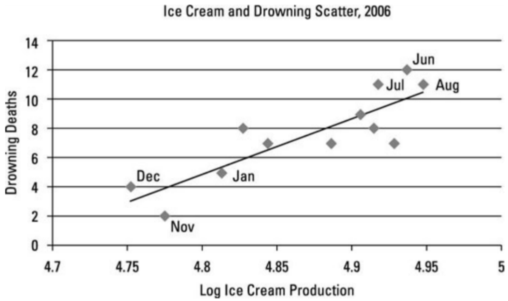
Many researchers believe that AI can only utilize "fast thinking" (System I). They propose causality to reach "slow thinking" (System II).

Correlation vs Causation



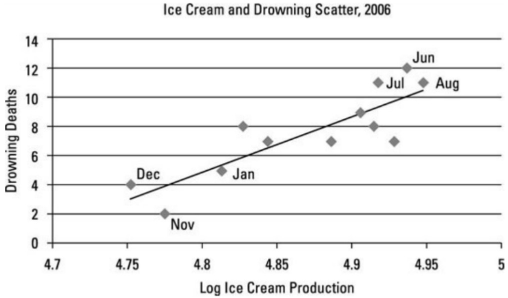
Does ice cream consumption cause drowning? Does the number of drownings cause ice cream cravings from the population?

Correlation vs Causation



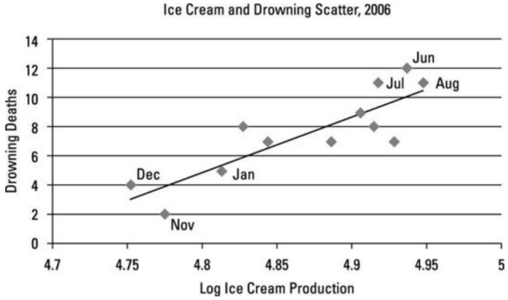
Does ice cream consumption cause drowning? Does the number of drownings cause ice cream cravings from the population?
Of course not, but there is a **third variable** that causes both: the month of the year.

Interventions



But how can we know if two correlated events have a cause-effect structure?

Interventions



But how can we know if two correlated events have a cause-effect structure?
By using **interventions!**
(e.g. If we force people to randomly eat ice cream, we will see that the number of drownings stays the same.)

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Synergies

- **Reinforcement Learning**: Learning to achieve a goal with interventions.
- **Causal Learning**: Learning how the world works with interventions.

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- **Reinforcement Learning**: Learning to achieve a goal with interventions.
- **Causal Learning**: Learning how the world works with interventions.

It looks like both of these learning methodologies revolve around **interventional data**.
Additionally, learning a more descriptive representation of the world (through causal learning) can help Reinforcement Learning.

The Field

The idea of joining Causality with Reinforcement Learning is called recently began to be explored and is called **Causal Reinforcement Learning**.

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[3]Source: `https://causalai.net/`

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Conclusion

- **What?**: ✓
- **Why?**: ✓
- **How?**: ✗
- **Where?**: ✗

I'm still working on the **How** and **Where** parts, which correspond to the **implementation** and **robotics use case**, respectively.