Online and Reinforcement Learning

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“Classical” (Batch) Machine Learning

Data

Machine Learning

Prediction rule

Assumption

“The future is identical to the past”

The samples are independent identically distributed (i.i.d.)

ASSUMPTIONTS

1. SAMPLES ARE i.i.d.
2. DATA AND NEW SITUATION ARE FROM THE SAME DISTRIBUTION

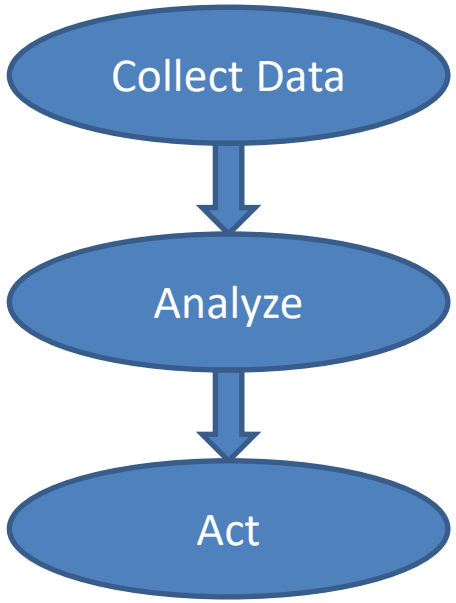
New situation

“What has been will be again, what has been done will be done again, there is nothing new under the sun.”

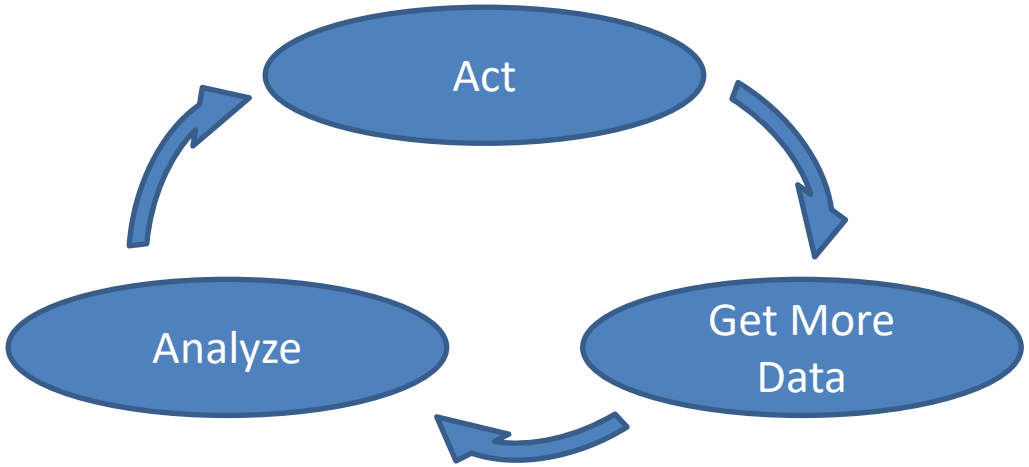
Decision/Action

How Online is different from “batch”?

Batch Learning



Online Learning



Examples

- Investment in the stock market
- Online advertising/personalization
- Online routing
- Games
- Robotics
- …

When do we need Online Learning?

there can be no objection to the use of data, however meagre, as a guide to action required before more can be collected

(Thompson, 1933)

When do we need Online Learning?

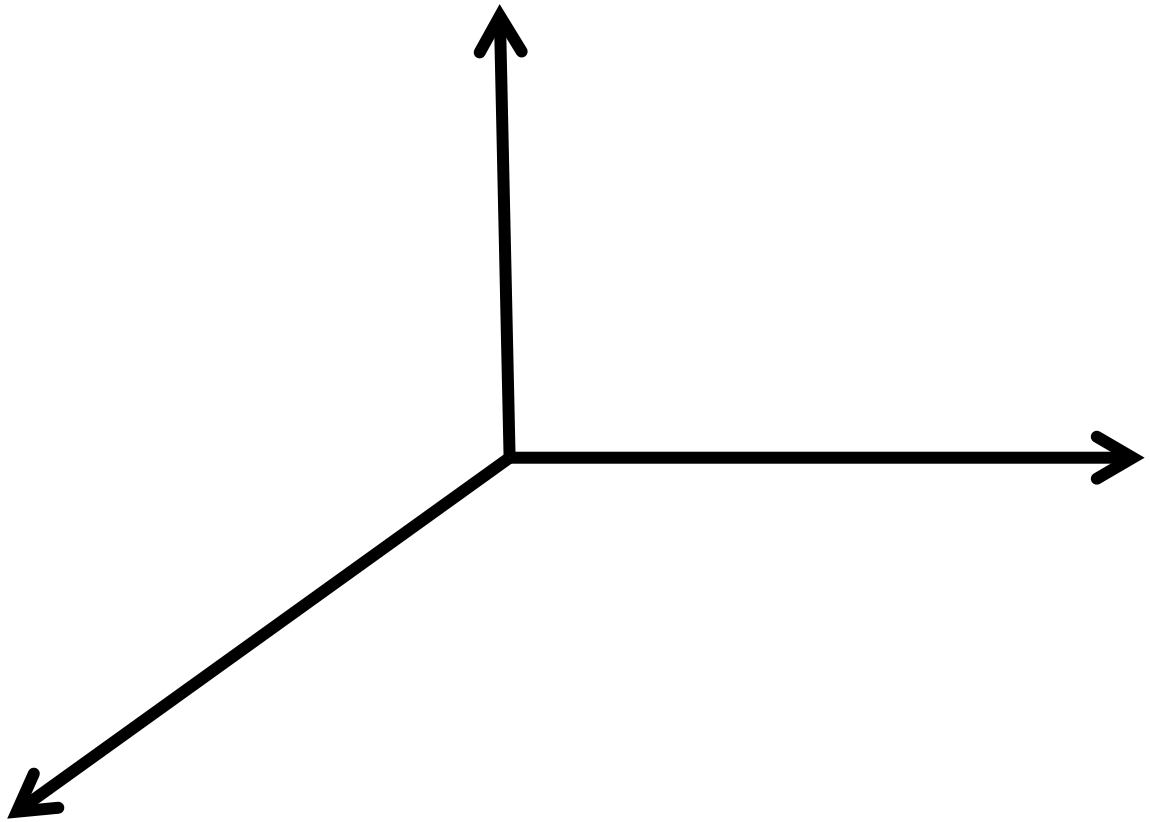
Until recently, statistical theory has been restricted to the design and analysis of sampling experiments in which the size and composition of the samples are completely determined before the experimentation begins. The reasons for this are partly historical, dating back to the time when the statistician was consulted, if at all, only after the experiment was over, and partly intrinsic in the mathematical difficulty of working with anything but a fixed number of independent random variables. A major advance now appears to be in the making with the creation of a theory of the sequential design of experiments, in which the size and composition of the samples are not fixed in advance but are functions of the observations themselves.

(Robbins, 1952)

When do we need Online Learning?

- Interactive learning
- "Adversarial" game-theoretic settings
  - No assumption on similarity of past and future
- Intelligent data collection
- Large-scale data analysis

The Space of Online Learning Problems



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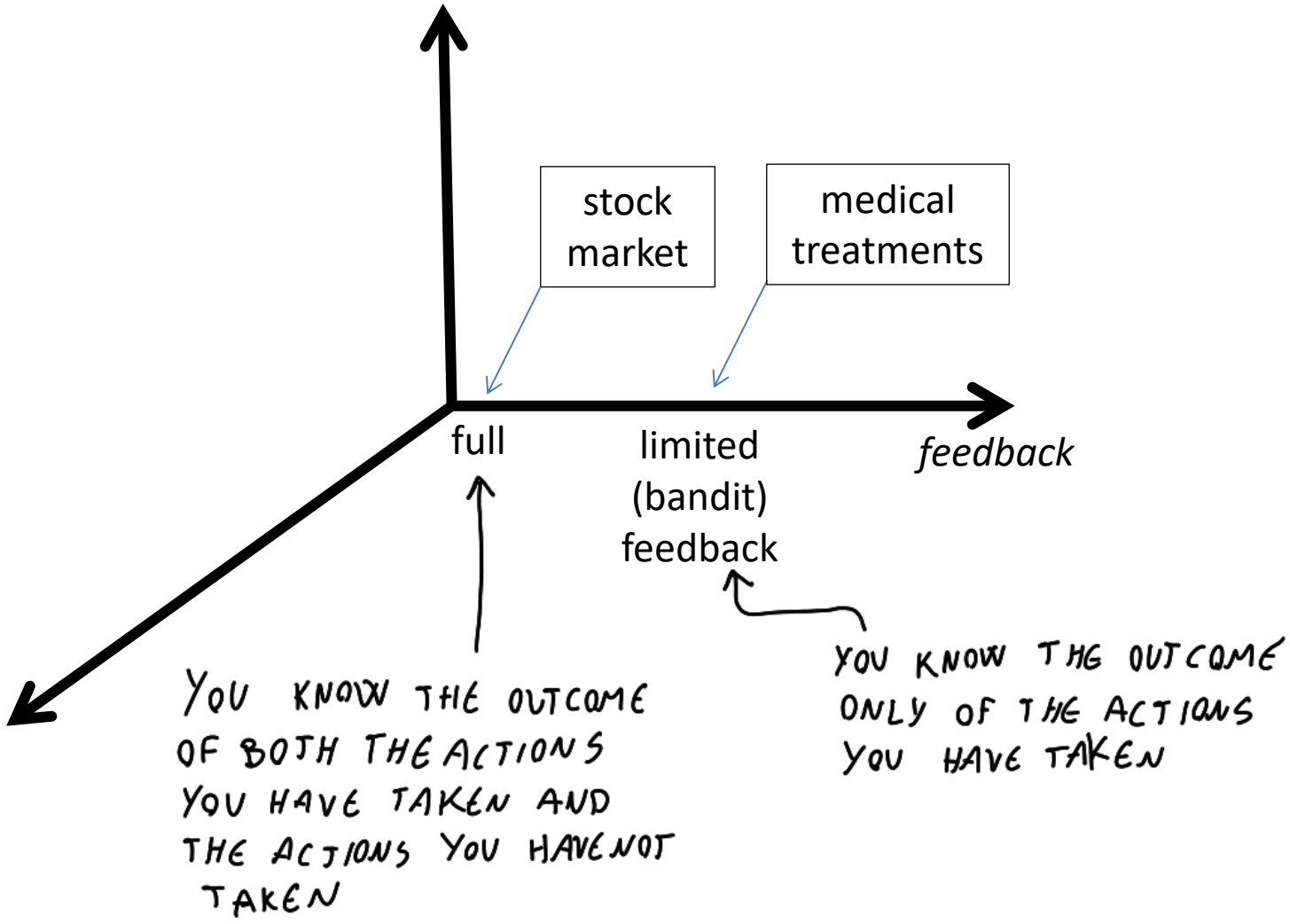

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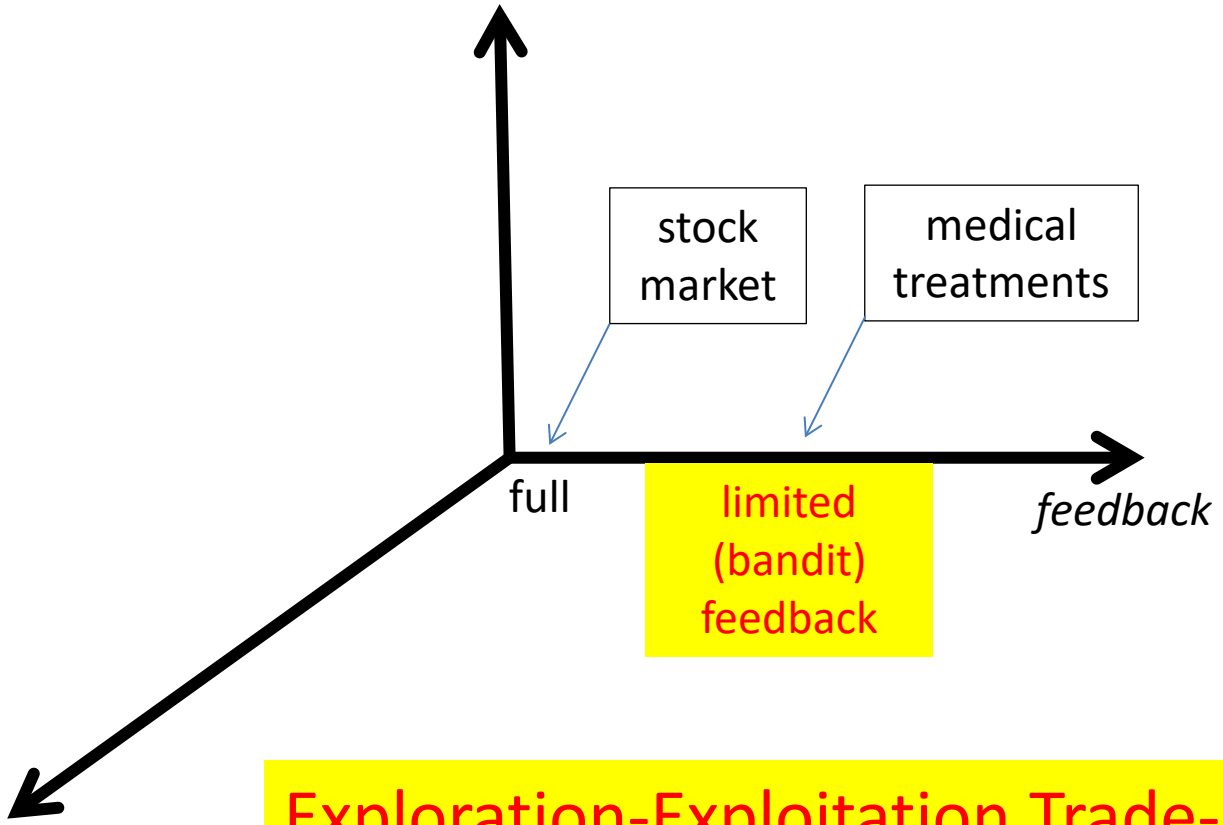
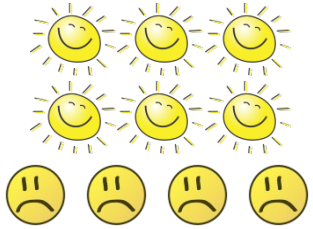


Exploration-Exploitation Trade-off

Exploration-Exploitation Trade-off

WE HAVE TO DO IT IN A SMART WAY, WE CAN'T JUST TRY THEM INDEPENDENTLY FROM THE PREVIOUS RESULTS

WE DON'T WANT TO WASTE POSSIBLY USEFUL INFORMATIONS



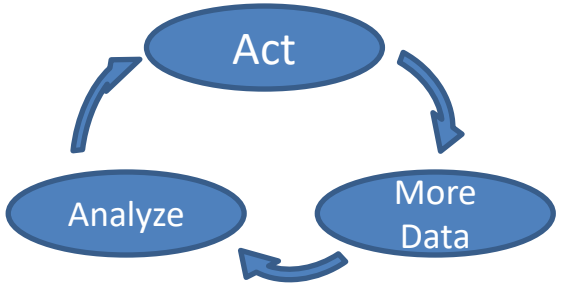
Never tried

0/2

6/10

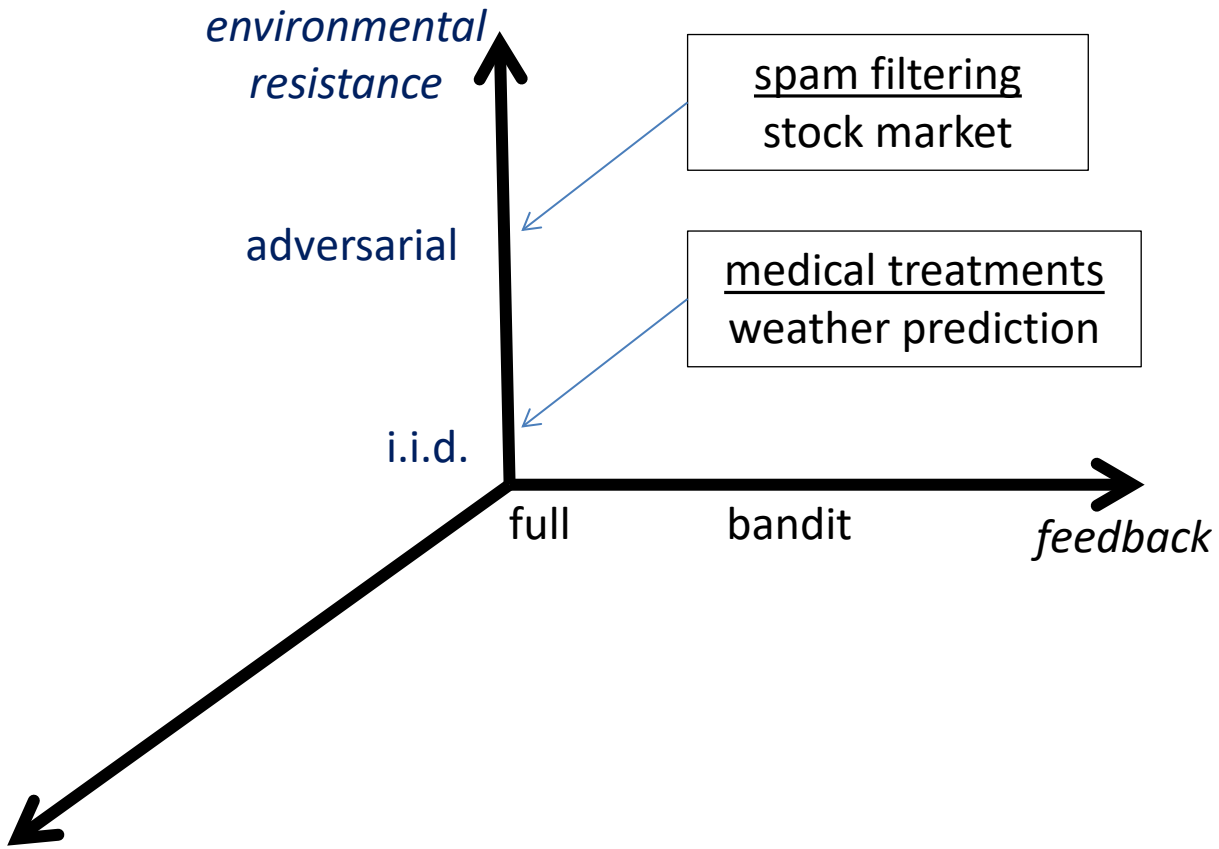
What drug to give to a new patient

When there are more patients to come…



We are building the dataset for ourselves

The Space of Online Learning Problems



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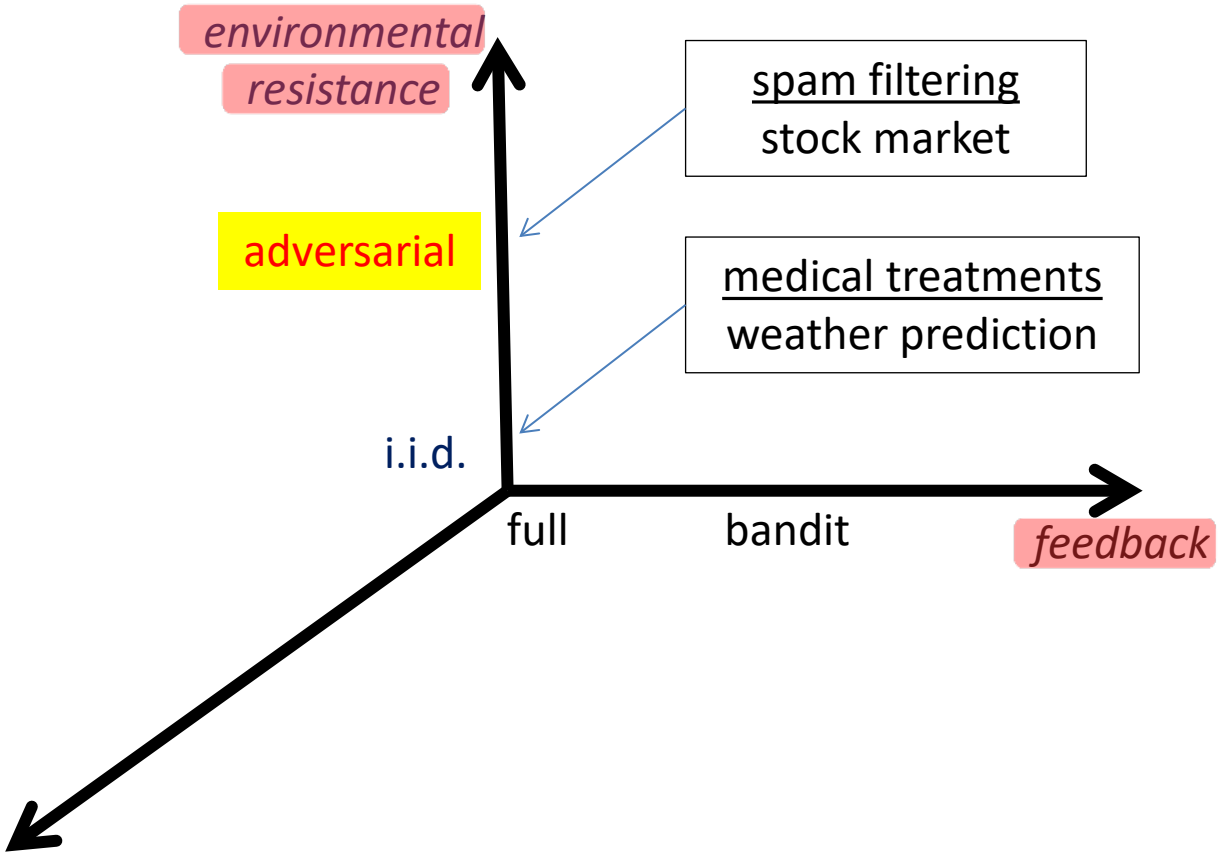
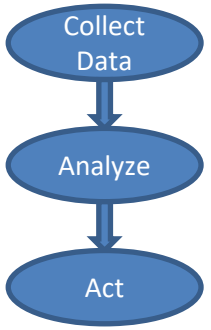
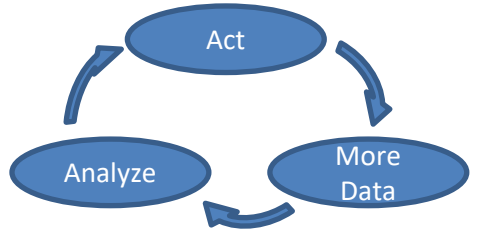


Learning in Adversarial Environments

- Game theoretic setting

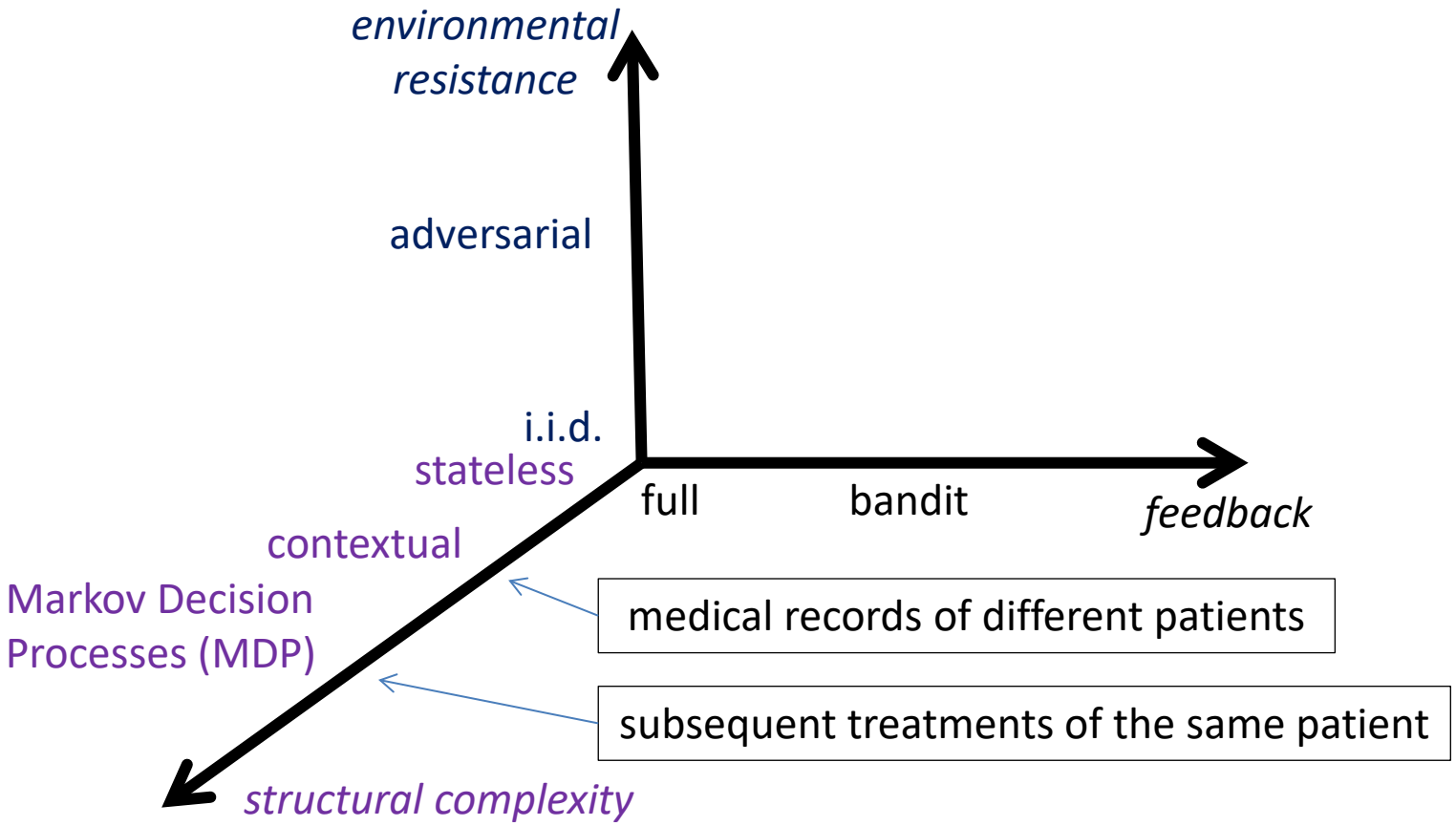
- Cannot be treated in batch learning





- Evaluation measure: *regret*
  - Difference in performance compared to the best choice in hindsight (out of a limited set)
  - E.g. investment revenue vs. the best stock in hindsight

The Space of Online Learning Problems



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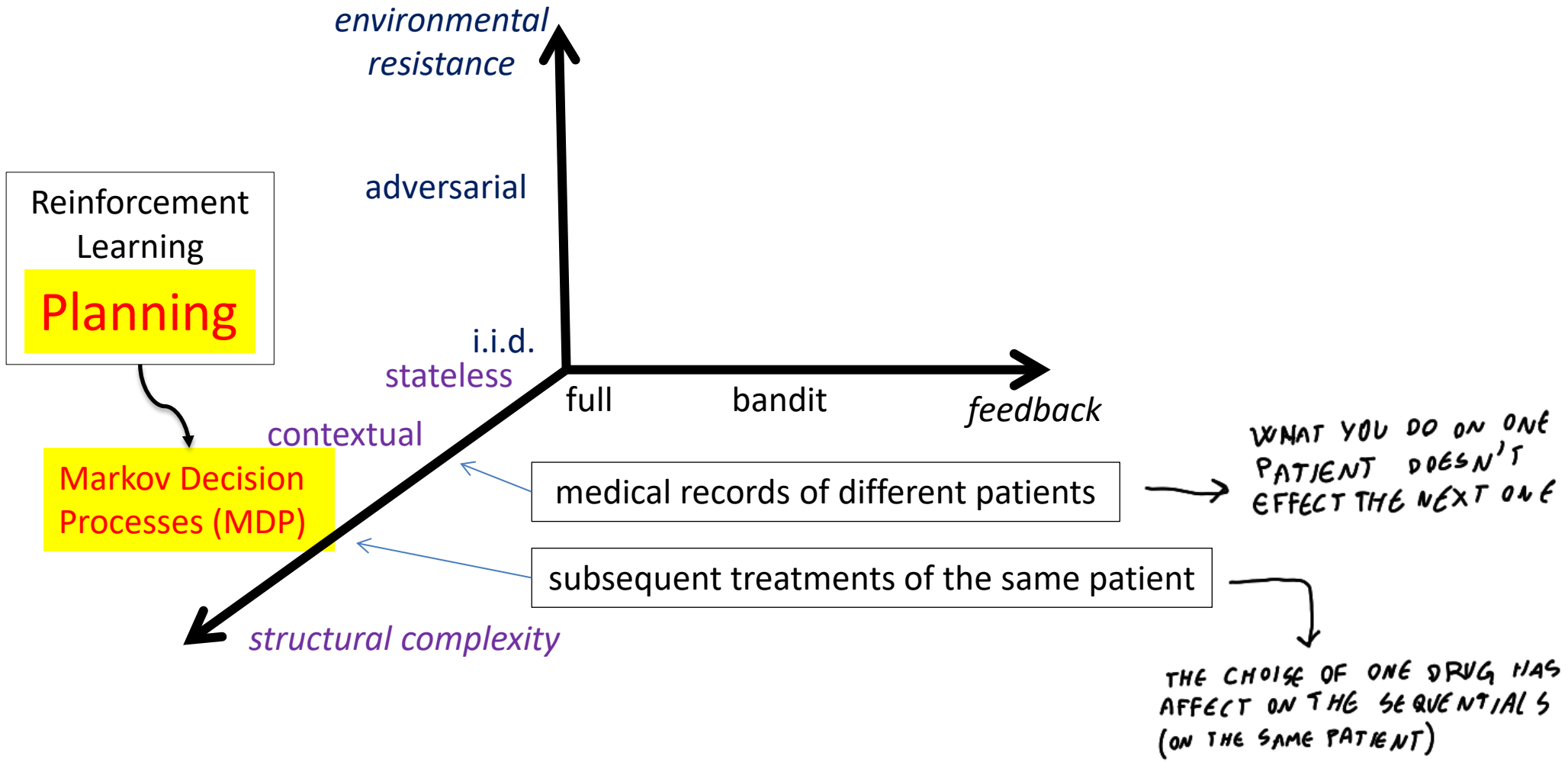
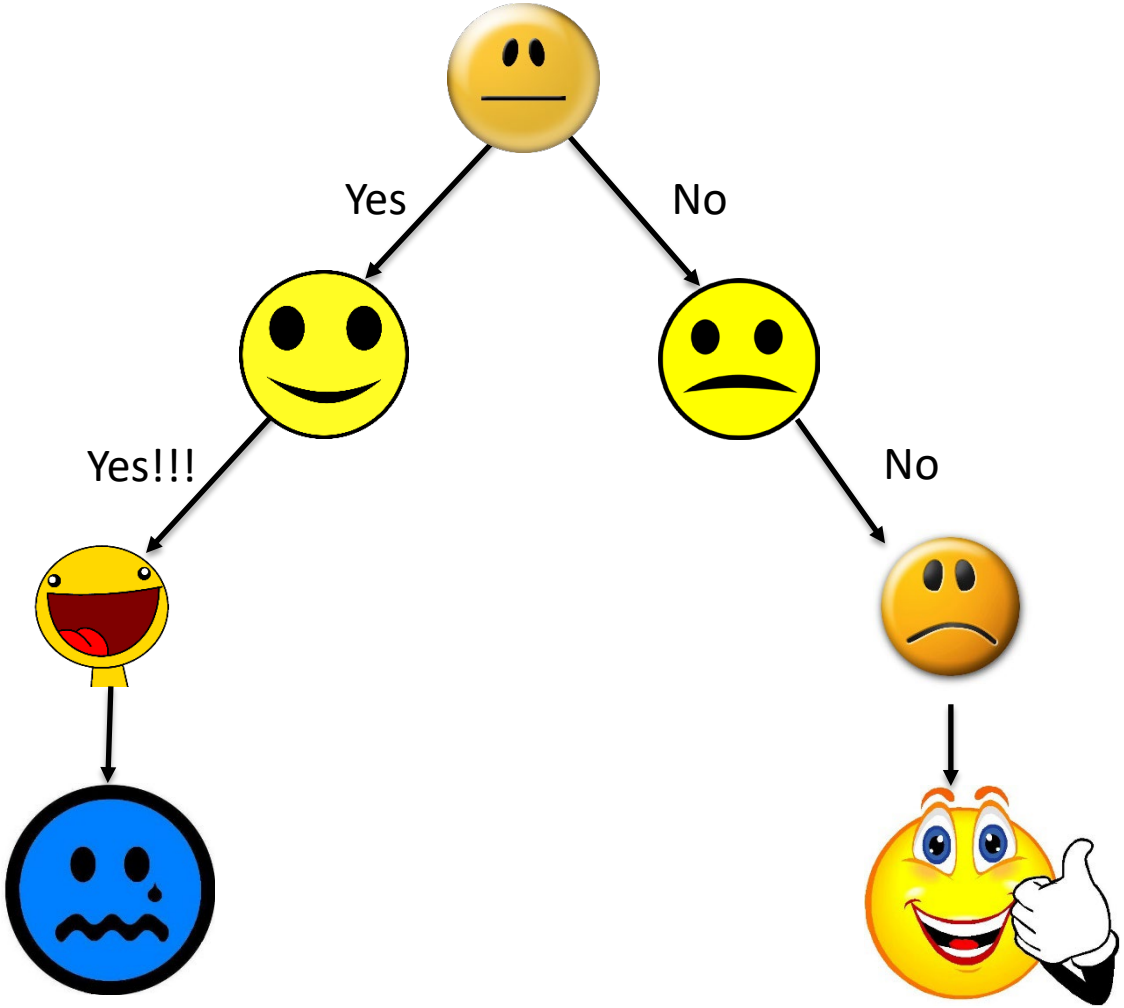


Planning

Would you like to have a drink?

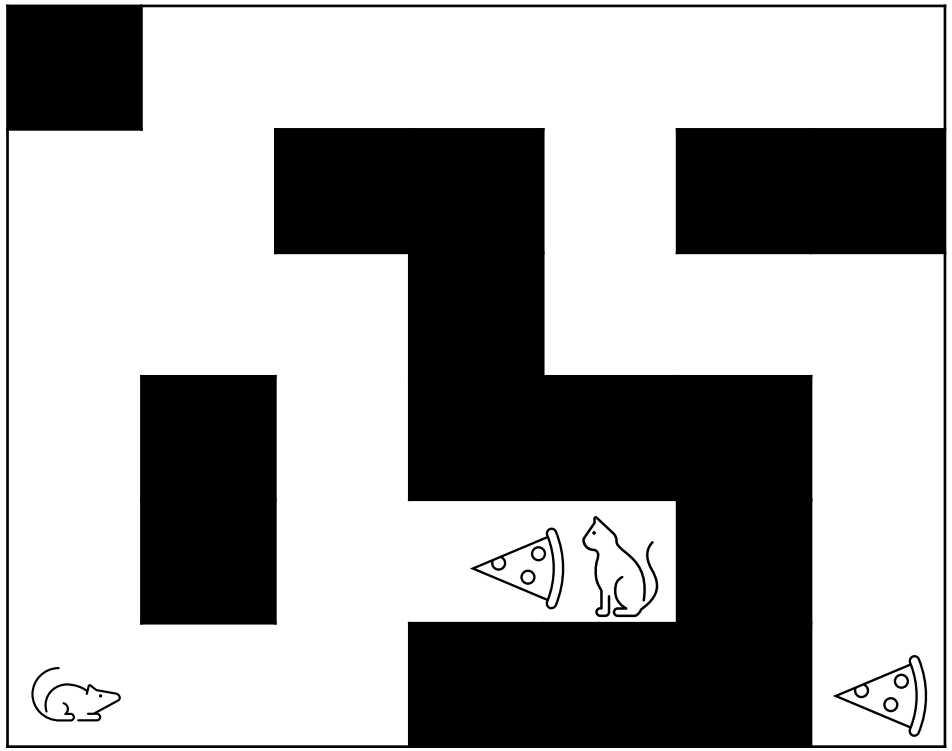
Would you like to have another drink?

The next morning….



Planning

- Even if the immediate outcomes are known, long-term goals require planning



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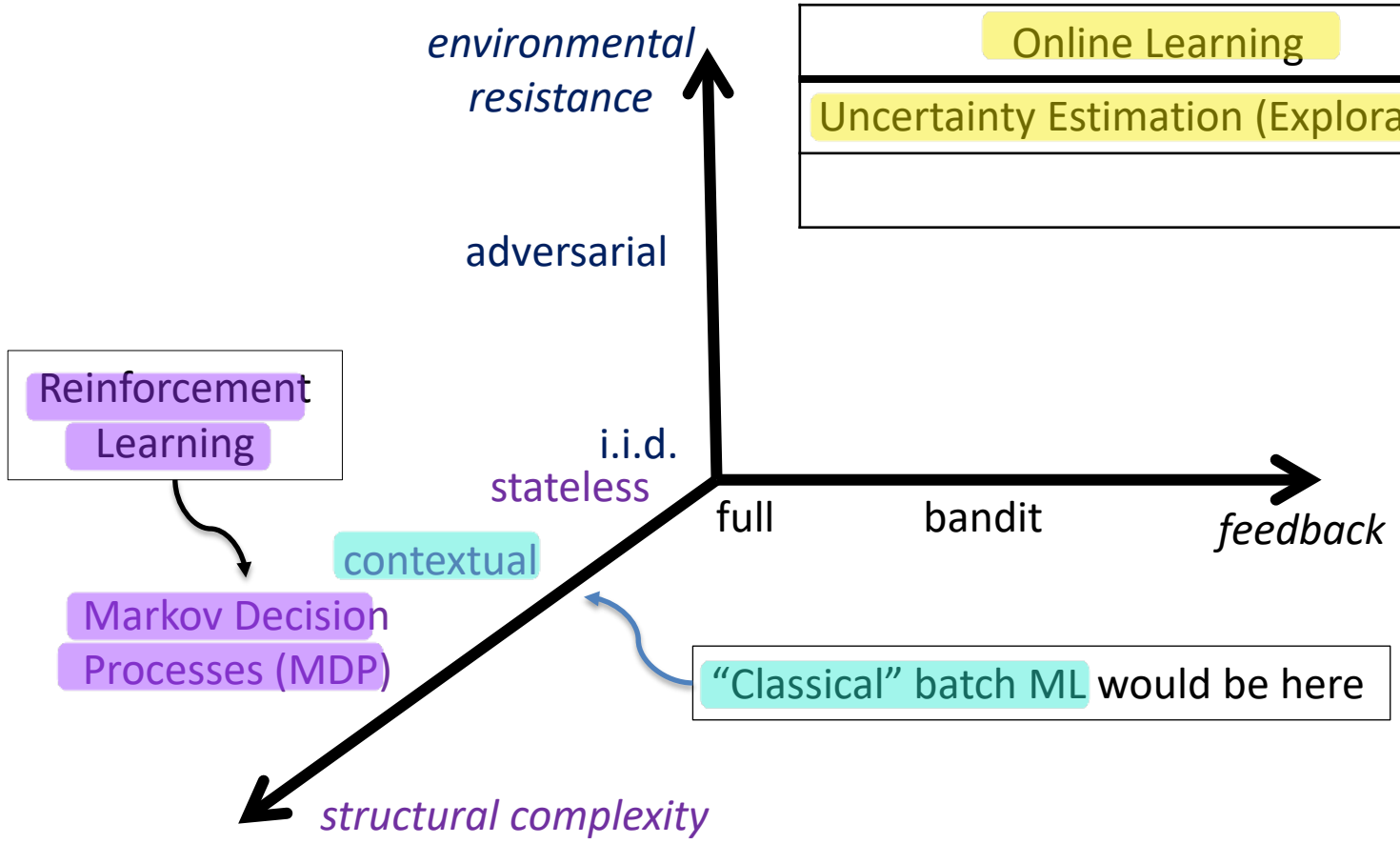

Online Learning	Reinforcement Learning
Uncertainty Estimation (Exploration)	Uncertainty Estimation (Exploration)
	Planning