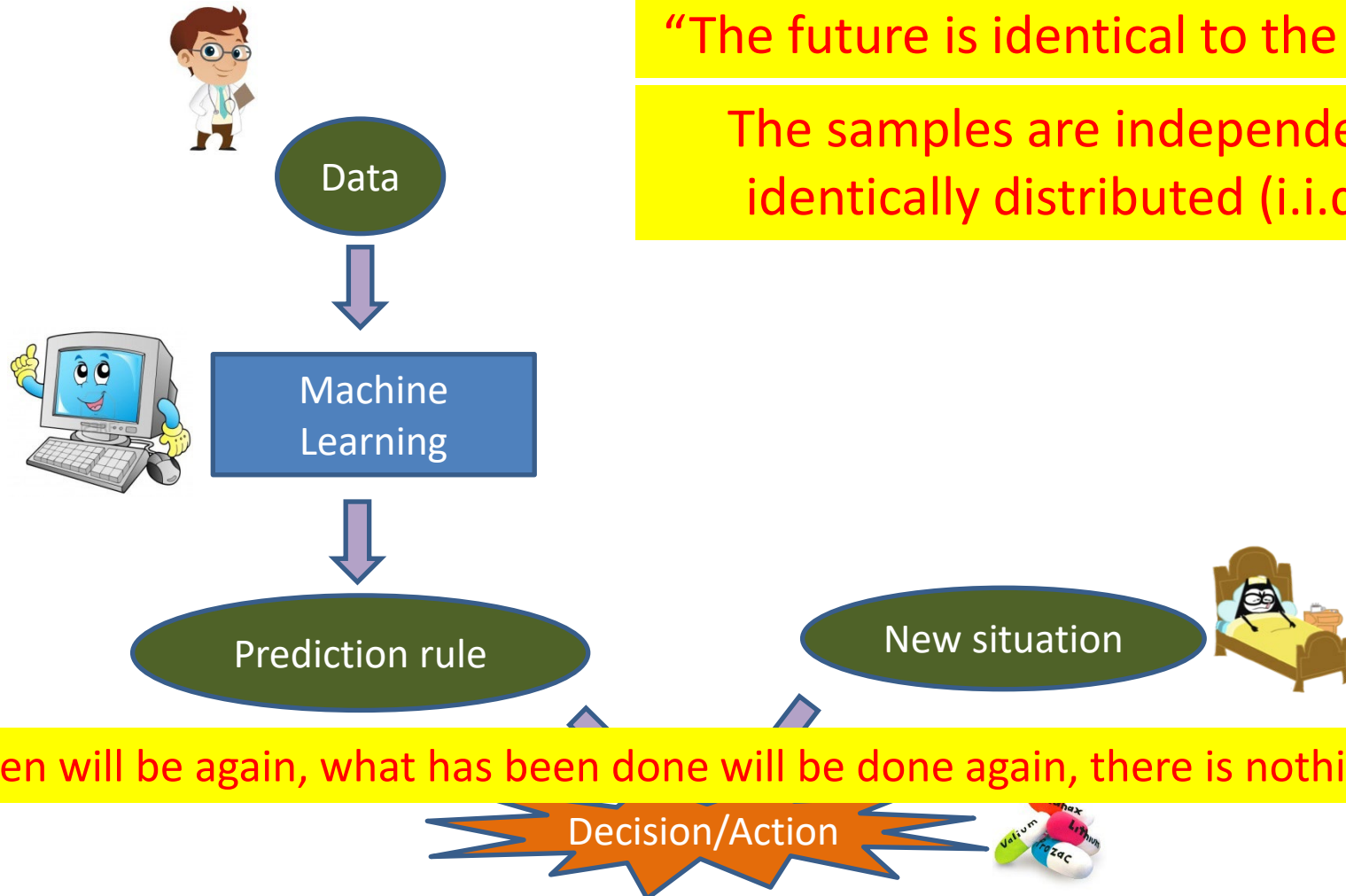


Online and Reinforcement Learning

Yevgeny Seldin

University of Copenhagen

“Classical” (Batch) Machine Learning



Assumption

“The future is identical to the past”

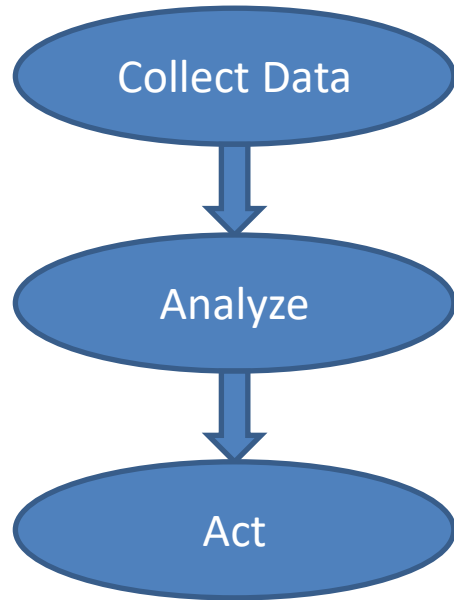
The samples are independent
identically distributed (i.i.d.)

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

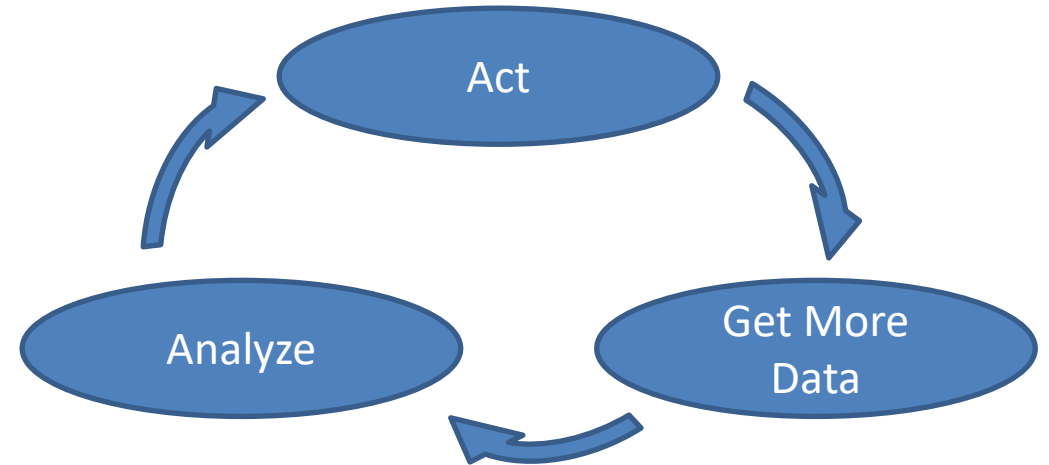
Decision/Action

How Online is different from “batch”?

Batch Learning



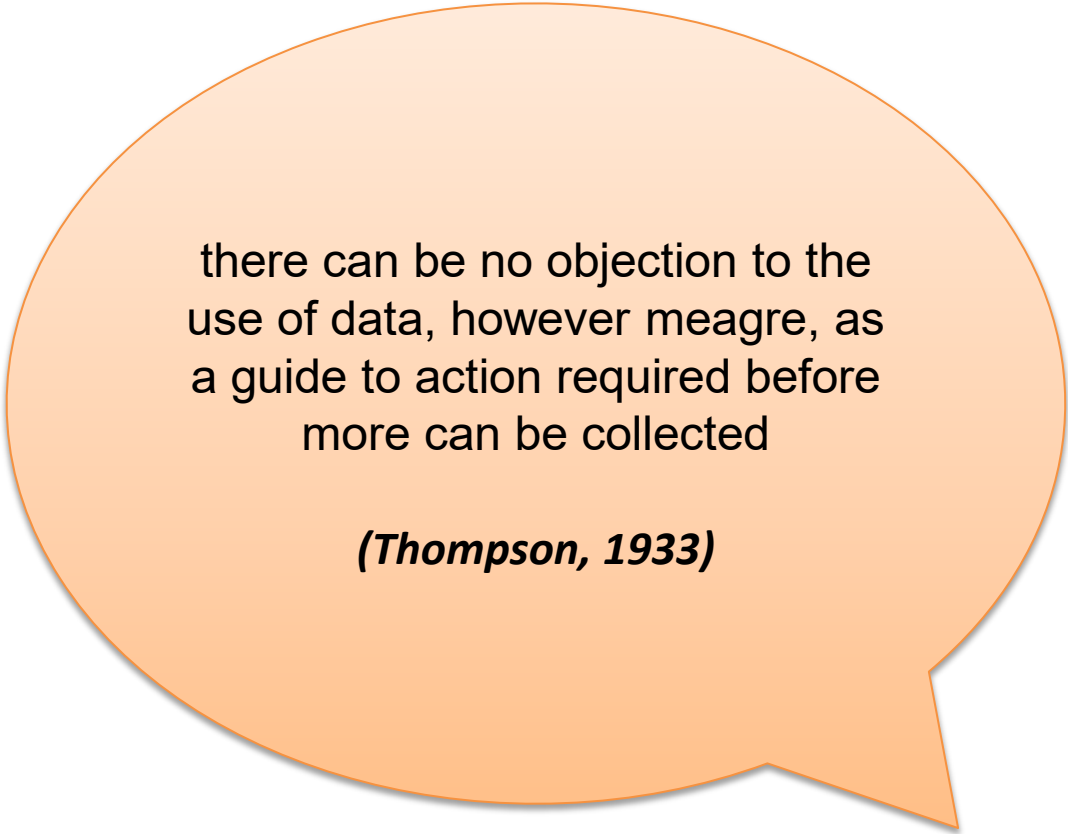
Online Learning



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.

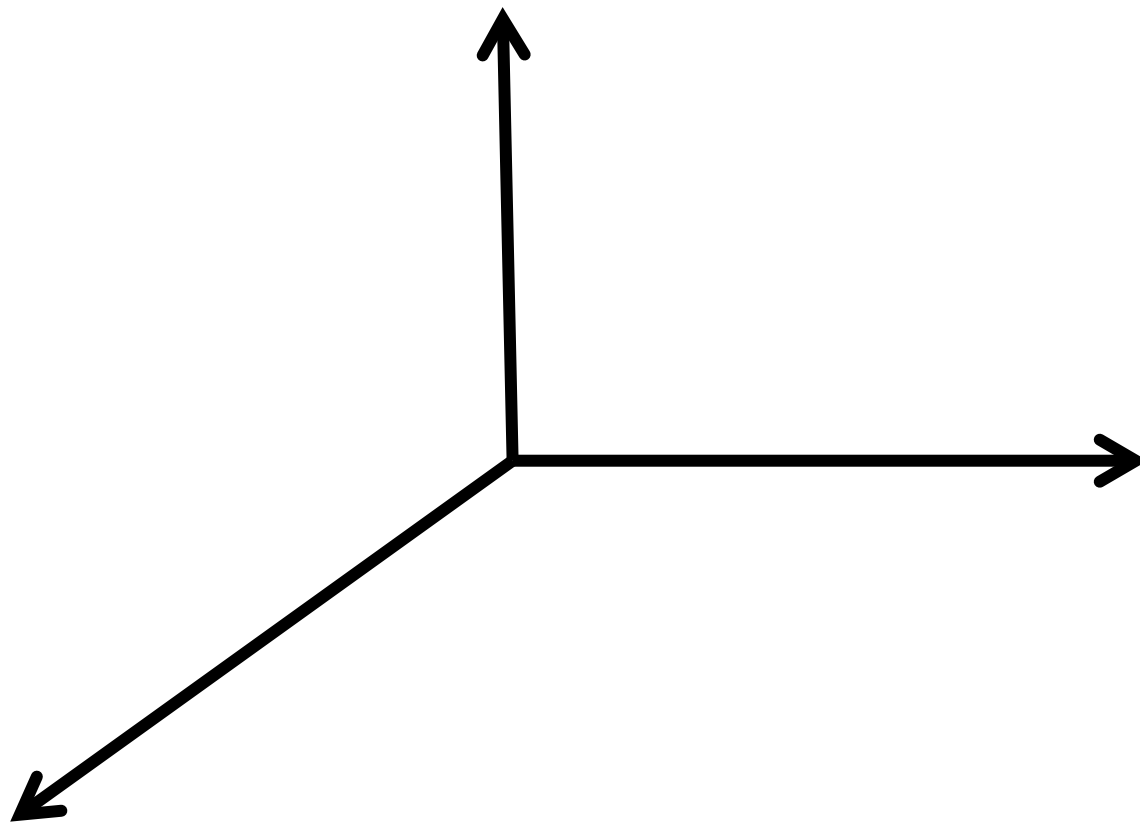
(Robbins, 1952)



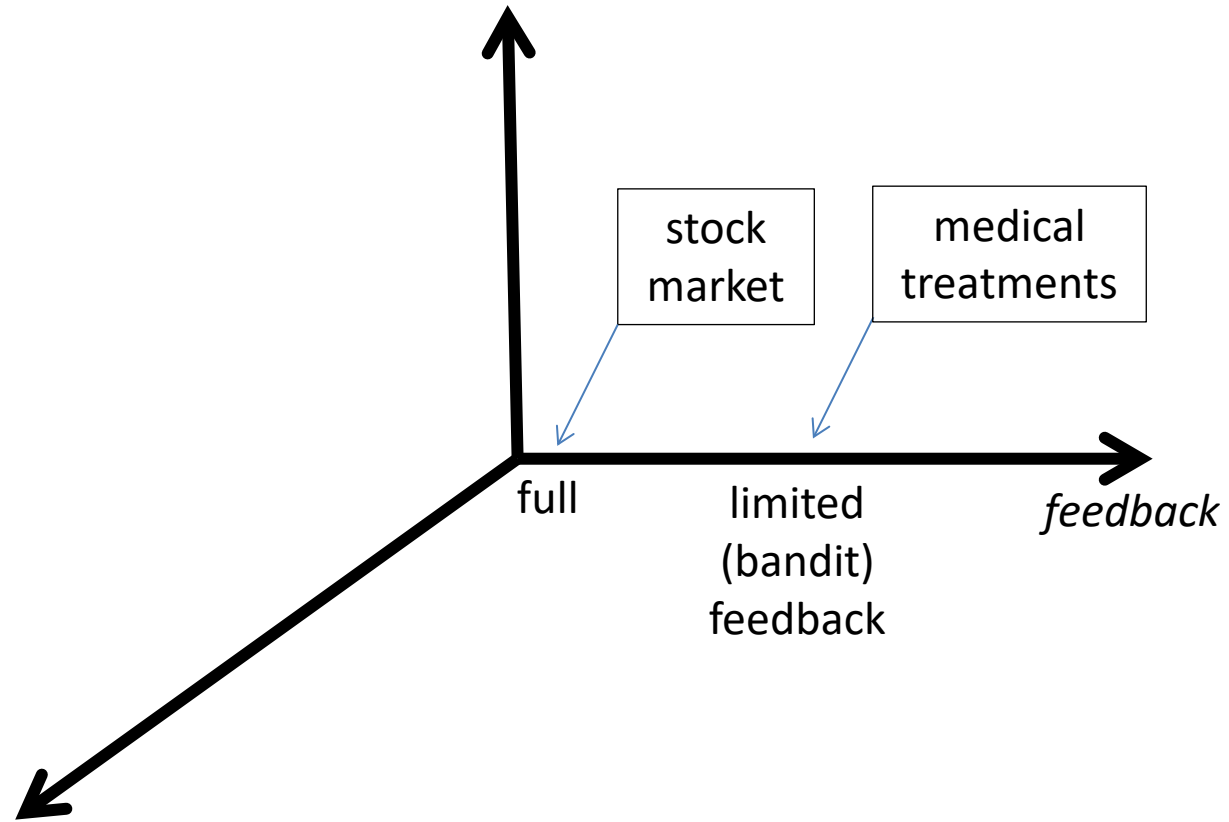
When do we need Online Learning?

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

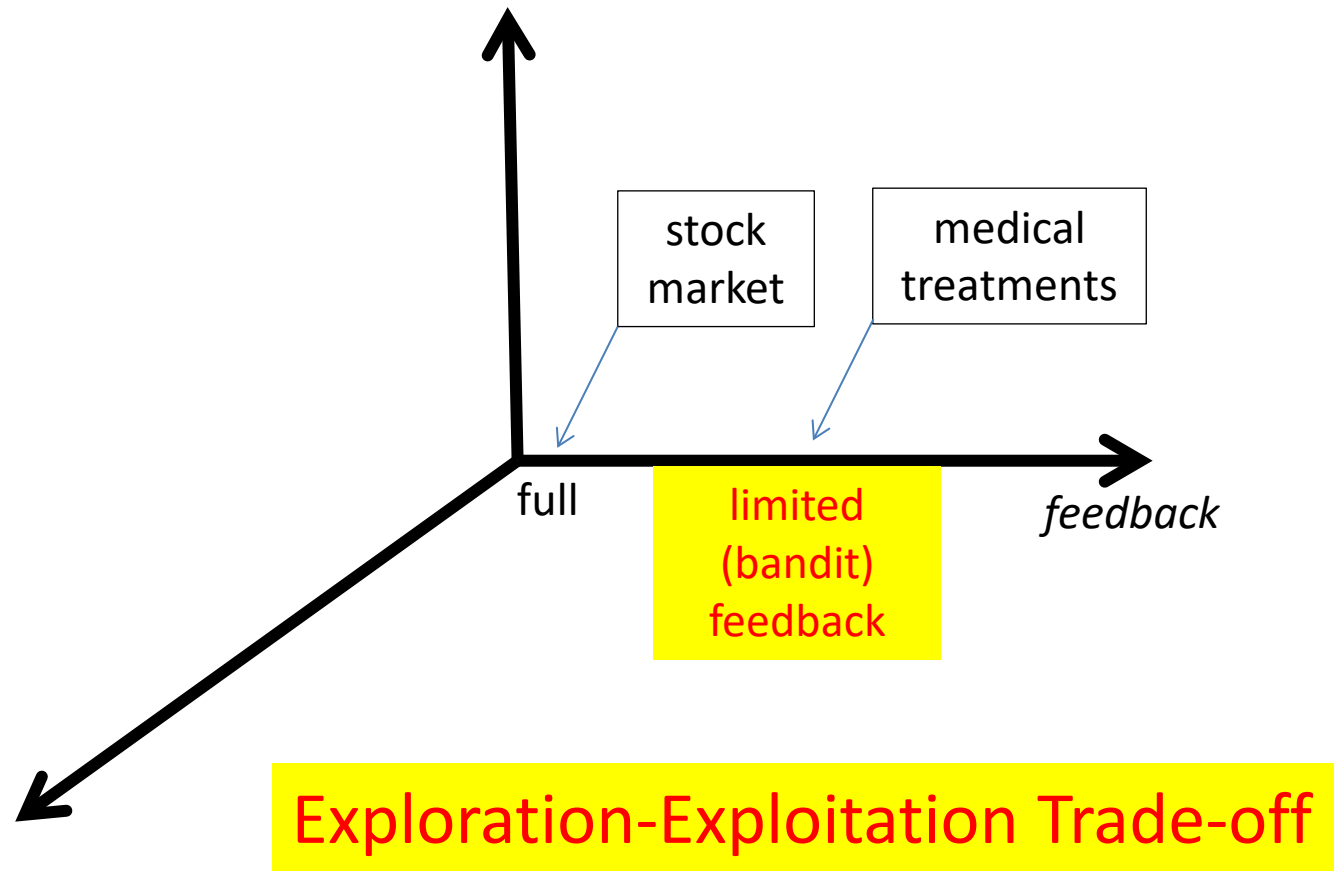
The Space of Online Learning Problems



The Space of Online Learning Problems



The Space of Online Learning Problems



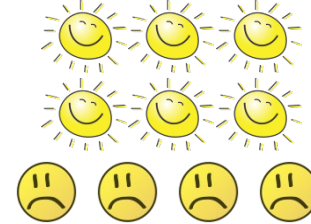
Exploration-Exploitation Trade-off



Never tried



0/2

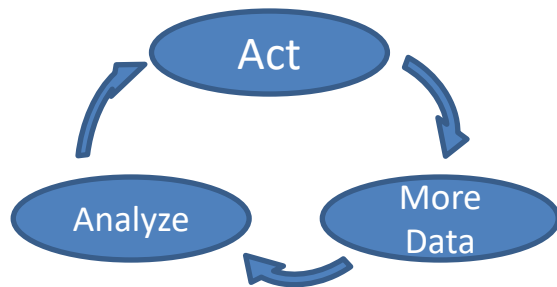


6/10

What drug to give to a new patient

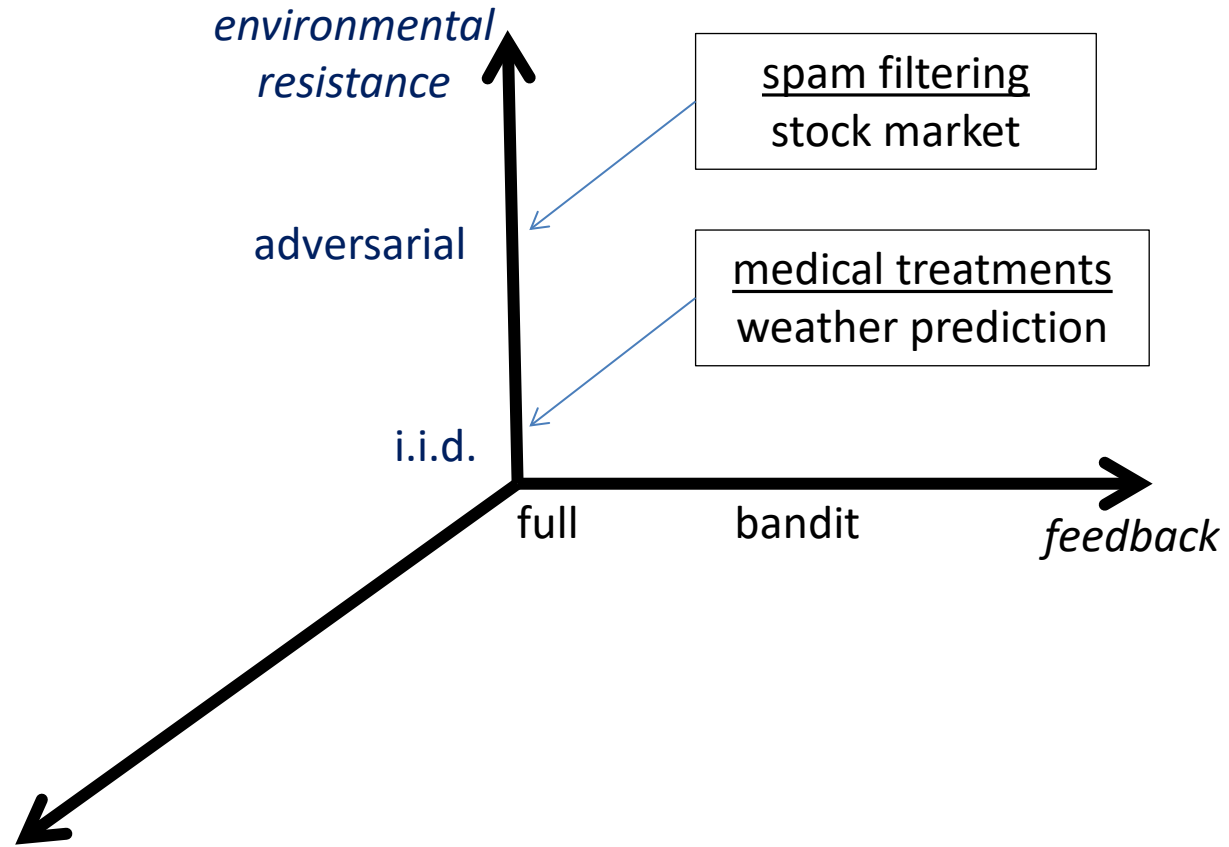


When there are more patients to come...

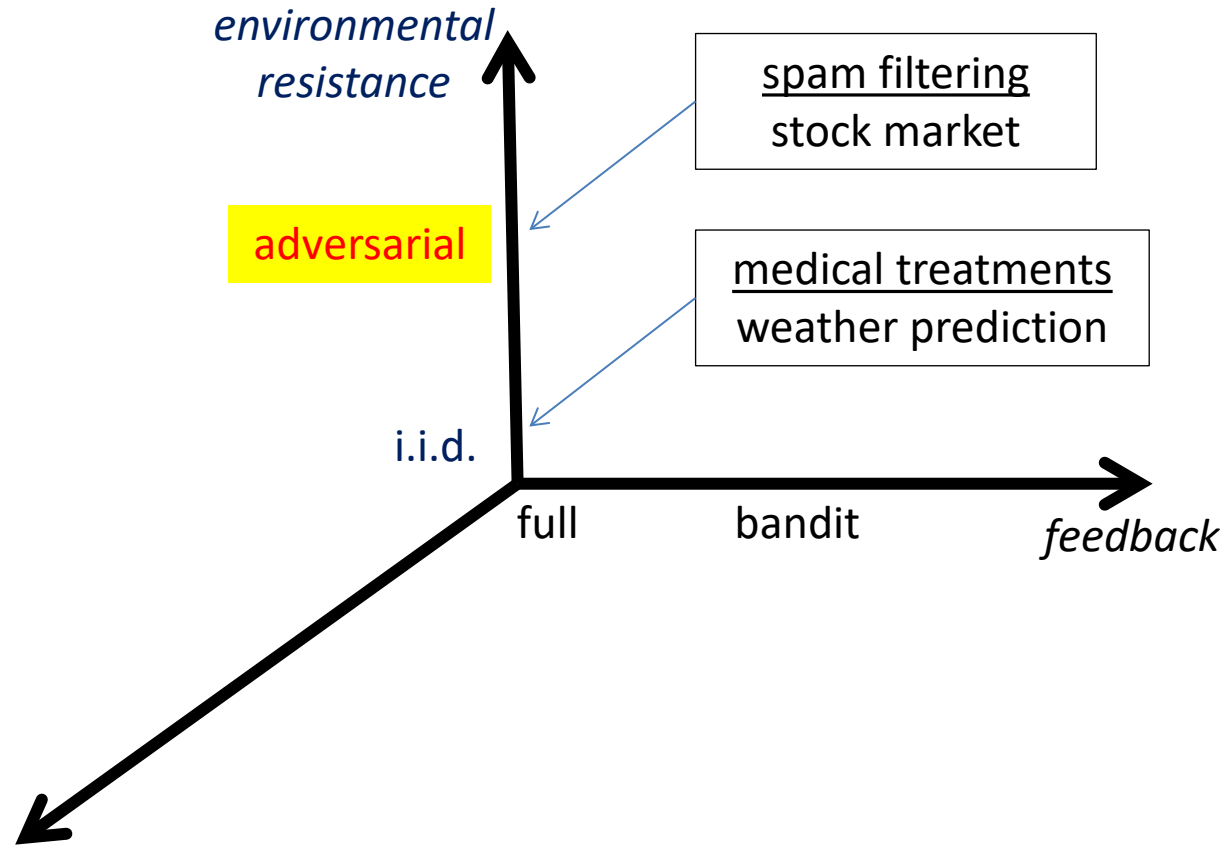


We are building the dataset for ourselves

The Space of Online Learning Problems



The Space of Online Learning Problems

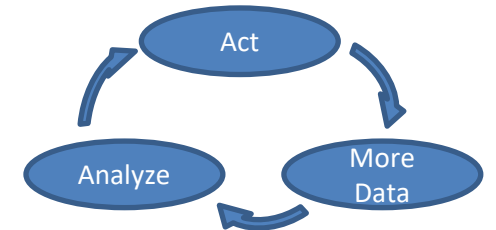
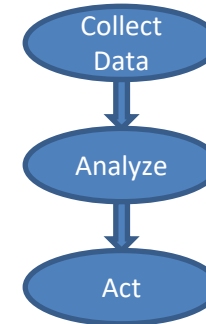


Learning in Adversarial Environments

- Game theoretic setting

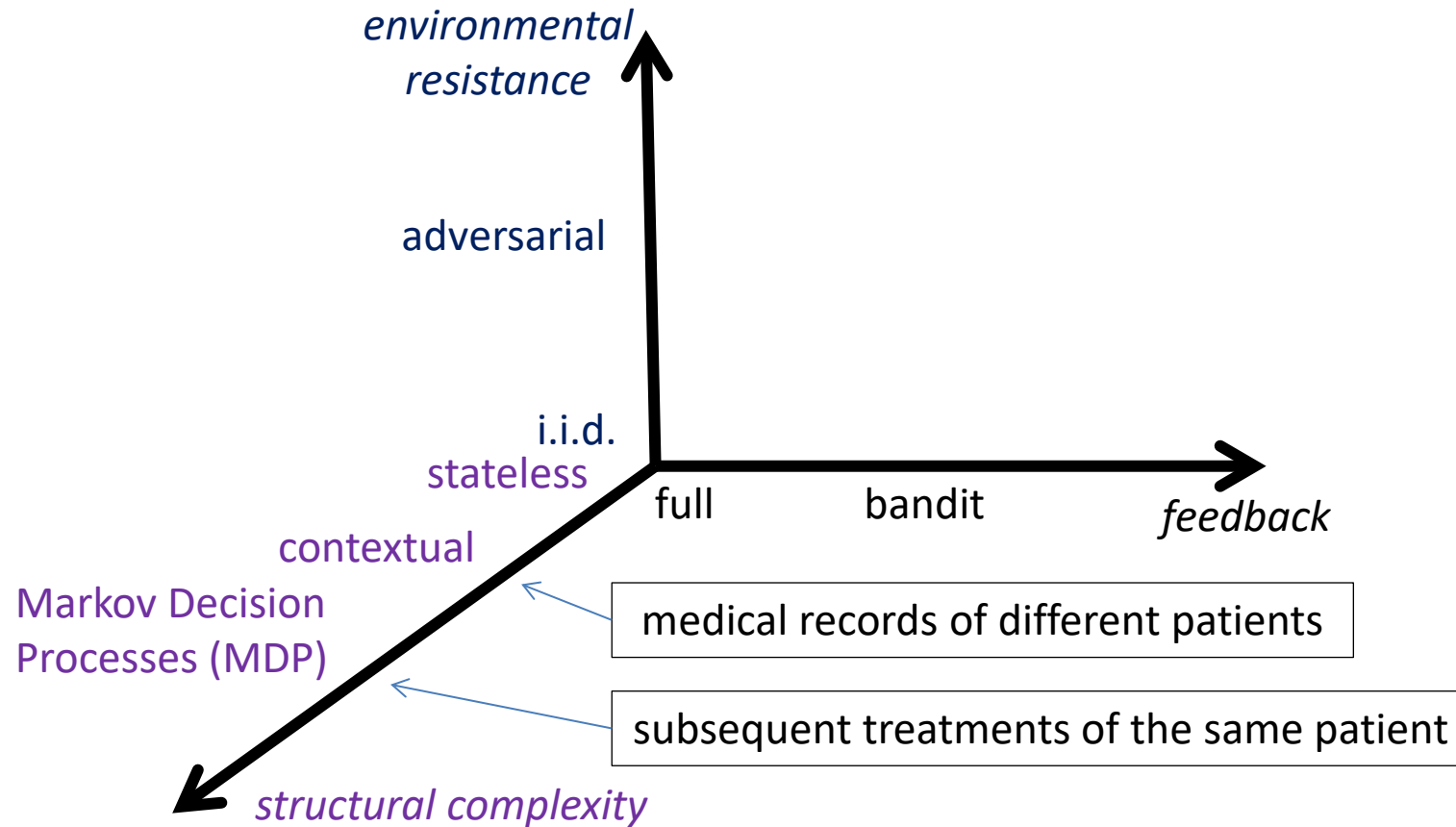


- Cannot be treated in batch learning

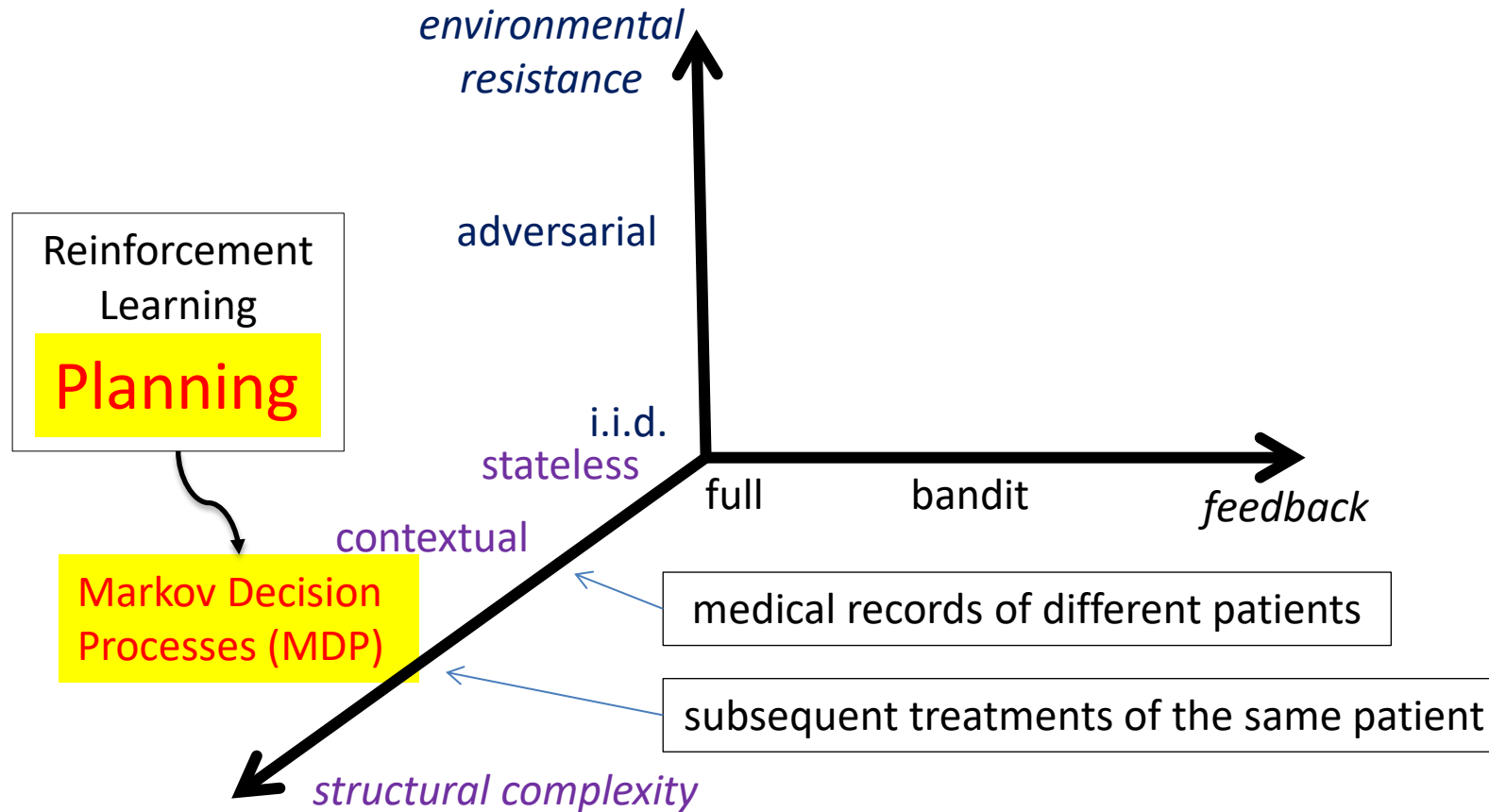


- Evaluation measure: *regret*
 - Difference in performance compared to the best choice in hindsight (out of a limited set)
 - E.g. investment revenue vs. the best stock in hindsight

The Space of Online Learning Problems



The Space of Online Learning Problems



Planning

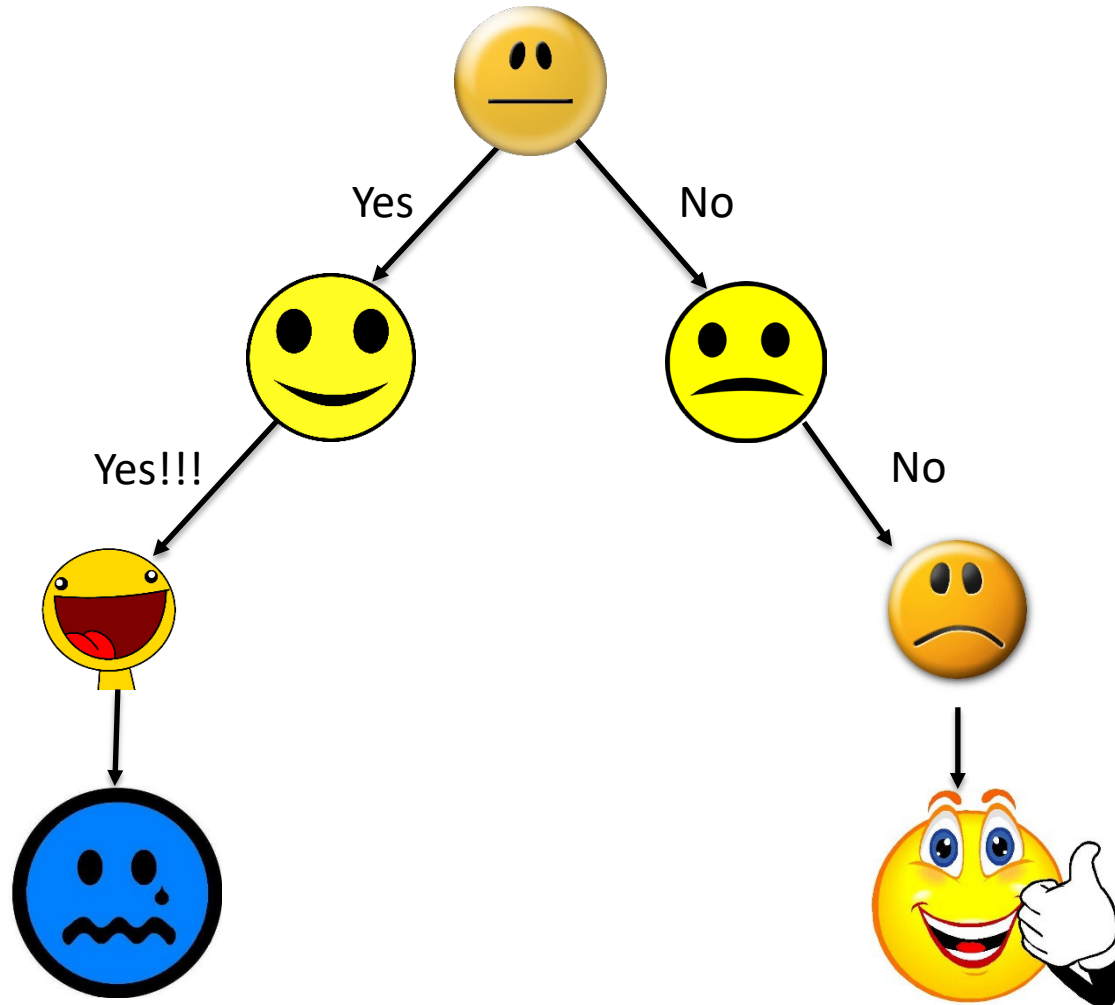


Would you like
to have a
drink?



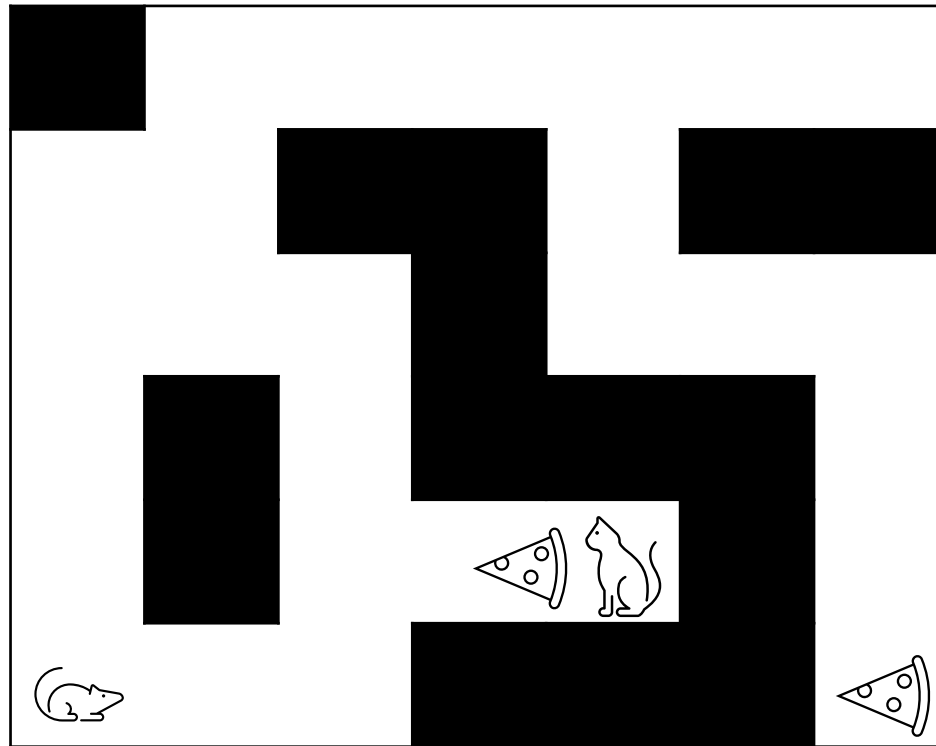
Would you like
to have
another drink?

The next morning....



Planning

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



The Space of Online Learning Problems

