



# *Machine Learning in Physics*

PHYS 449



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# Preface

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# Machine Learning Primer

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## 1.1 Introduction to learning

What does it mean for a computer to learn? See a quote from T Mitchell '97. This is learning, but not intelligence.

Does that mean the algorithm is intelligent? Should real-world events be thought as probabilistic events? These questions do not have definite answers. Nowadays, AI is 99% deep learning, algorithms.

Learning algorithms are often divided into 3 paradigms: unsupervised, supervised, reinforcement learning.

Supervised learning is the most common form of ML. The task is to learn a mapping of inputs  $x \in X$  to outputs  $y \in Y$  so we are really just trying to learn the function  $f : x \mapsto y$ .

- $x$  is called feature. Some related fields include feature engineering.
- An experience  $E$  is a correct pairing  $(x, y)$ .
- A training dataset is a collection of experiences  $D = \{(x_1, y_1), \dots, (x_N, y_N)\}$ .
- $y$  often called label.
- Such datasets are called labeled datasets.

Finding a good dataset is hard.

A working example is solving many-body physics problems. Consider a 2-D toroidal lattice of spin sites.

$$E(s) = -J \sum_{\langle ij \rangle} s_i s_j$$

$s_i$  is spin state at site  $i$  of lattice.  $E(s)$  is energy.  $J$  is coupling constant. One tries to minimize the energy.

Supervised learning relies on existence of labelled dataset. Unsupervised learning “makes sense of” data. Dataset  $D$  without any corresponding output labels  $y_n$ . Basic techniques include clustering, dimensionality reduction. So it is fitting an unconditional model of the form  $p(x)$ , which can generate new data  $x$ .

Another common classification of ML models: discriminative/generative.

Reinforcement learning views the model as an agent, learning how to interact with its environment. The goal of agent is to learn optimal policy of what actions to take in a given environment. The agent does not know the best action, but receives occasional reward in response to its actions. It has close connections to control theory.