第二讲
技术背景（II）
Lecture 2
Technical Background (II)

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计算范式
Computing Paradigm

- 当神经网络提出后，尽管在一段时间内取得了一些成果，但并没有像预想那样地繁荣起来。当我们回过头再思考这个问题时，有以下一些原因：
  - 在用传统用算法解决问题时，人们对算法本身的原理是十分明晰的；但对于神经网络，可能是一知半解。即人们对神经网络的计算范式与传统计算范式的差别，不是一开始就十分明了的；
  - 在明确计算范式之后如何实施，在较长一段时间内没有较好的方案；更有甚之，当有了好的方案之后，如何高效的实施，可能也要等到计算技术发展到合适的时机。

The evolvement of neural network has been fluctuating since the emergence of it. Although some progress was made for a period of time, it didn't gain popularity as expected. Retrospect reveals possible reasons summarized as follows:

- People usually have a clear understanding of the principles when solving problems using traditional algorithms; however, when comes to neural networks, the understanding might be partial or incomplete. Aka, the differences between the computational paradigm of neural networks and traditional computing paradigms weren't initially well understood.
- Even after figuring out the most appropriate computational paradigm, there wasn't a good implementation instantly. Even a feasible solution was proposed, efficient implementation of it had to postpone up to the right stage of computing technology.

编程范式
Programming Paradigm

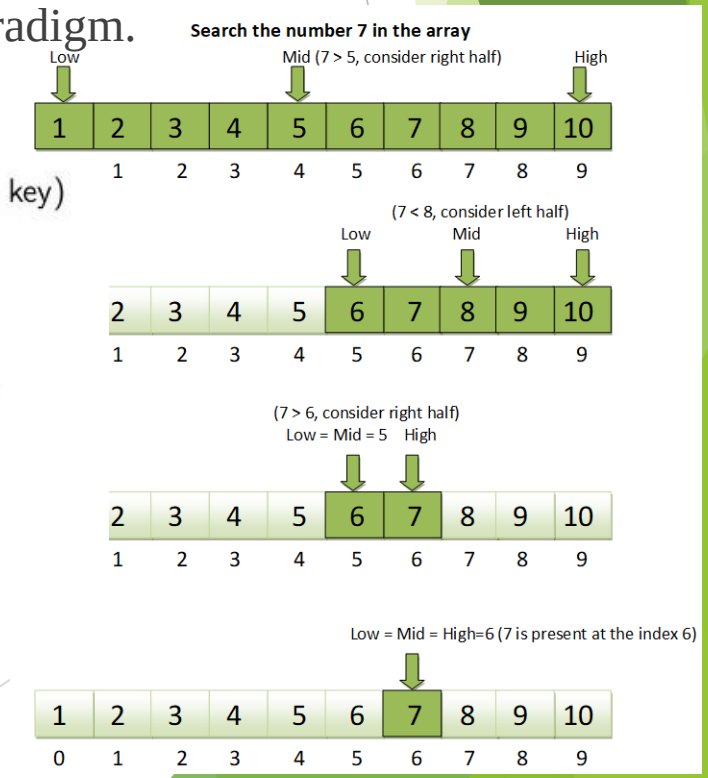
- 无论利用传统算法还是人工智能算法，基本都是通过编制程序利用计算机解决，因此，计算范式在不引起误解的情况下又被称为编程范式。

  Whether using traditional algorithms or artificial intelligence algorithms to solve problems, it tends to implement these algorithms through programming. Therefore, the computing paradigm, without causing misunderstanding, is also referred to as the programming paradigm.

- 通常，人们认为传统算法属于显式编程，即人们对基于算法本身要做的每一步十分明晰，且算法本身的成功实施不依赖于数据。传统算法的一个例子是如右图所示的二分查找算法：

  Usually, people consider traditional algorithms as part of explicit programming, where individuals have a clear understanding of each step involved in the algorithm itself, and the successful implementation of the algorithm does not rely on data. An example of a traditional algorithm is the binary search algorithm, as shown in the diagram on the right

```
BinarySearch(list[], min, max, key)
while min ≤ max do
  mid = (max+min) / 2
  if list[mid] >key then
    max = mid-1
  else if list[mid] <key then
    min = mid+1
  else
    return mid
  end if
end while
return false
```



编程范式
Programming Paradigm

- 隐式编程就是由模型或算法自动学习解决问题的步骤，而不用手工声明。以大家可能业已知道的用神经网络解决图像分类问题为例。我们不会关心模型是如何运作的，我们只需在训练阶段与测试阶段提供符合要求的数据即可。

  Implicit programming means that models or algorithms automatically learn the steps to solve problems without manual specification. Take, for example, solving image classification problems using neural networks, which many of us might already be familiar with. We don't concern ourselves with how the model operates; we simply provide the required dataset during the training and testing phases.

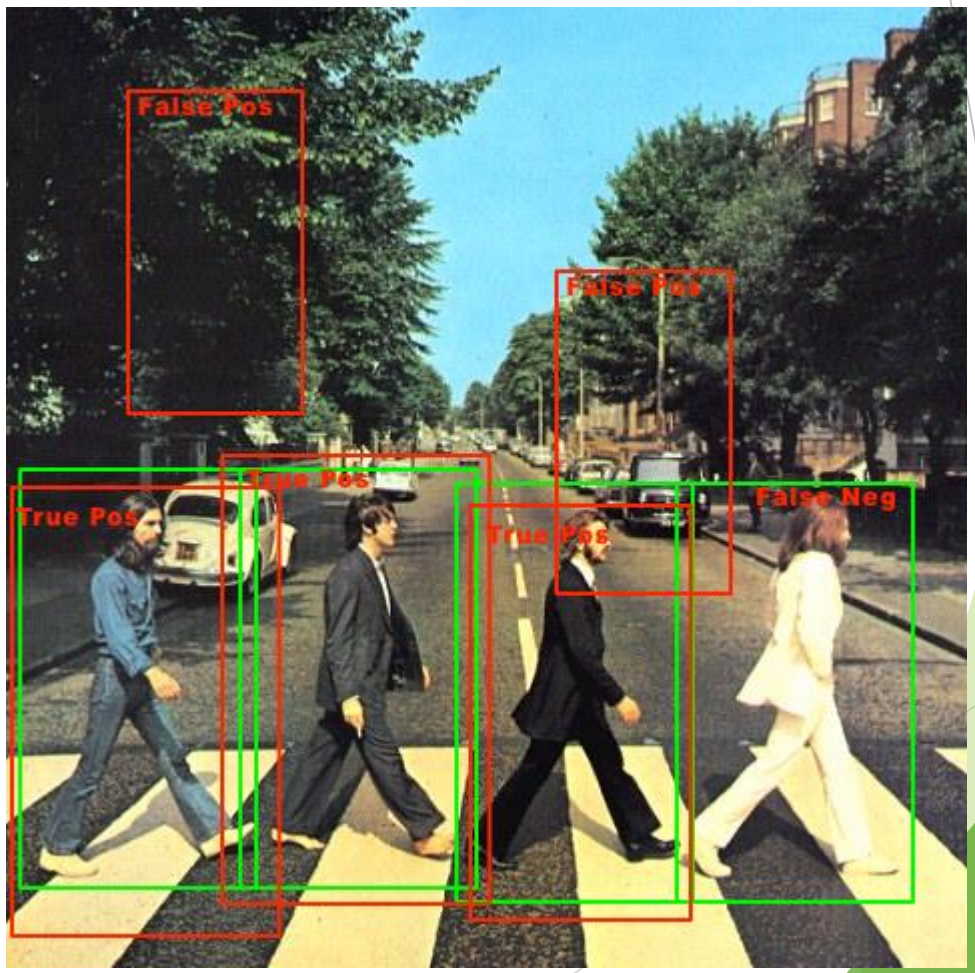
- 更具体地，考虑计算机视觉，其是一门研究如何使计算机能够模拟人类视觉系统，从图像或视频数据中获取信息、理解场景、识别物体和执行其他与视觉感知相关任务的学科。我们来分析基于传统算法与基于智能算法的编程的区别。

  More specifically, consider computer vision (CV), which is a discipline studying how to enable computers to simulate the human visual system, extracting information from image or video data, understanding scenes, recognizing objects, and performing other tasks related to visual perception. We will compare the difference between using traditional CV algorithms and recent intelligent algorithms.

编程范式
Programming Paradigm

- 以图像分类为例，基于传统CV算法，会明确定义一系列窗口，然后在给定图片上滑动，对每个位置的内容与给定模板进行匹配或进行特征分析，最后再由分类算法如SVM给出分类结果。

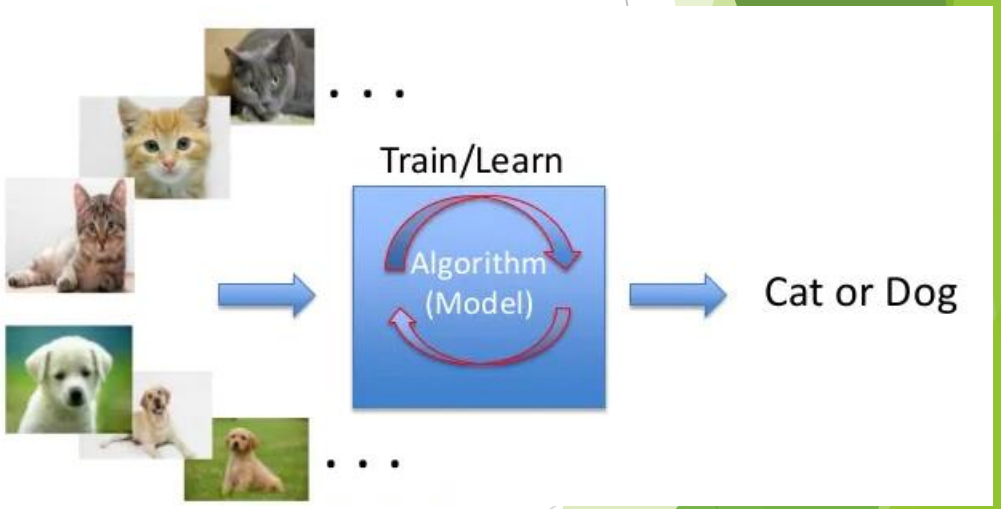
  Taking image classification as an example, based on traditional computer vision algorithms, a series of windows with different patterns are firstly defined. Then, these windows slide across a given image, matching the content at each position with the specified template or to analyze the features. Finally, a classification algorithm like SVM provides the classifications.



编程范式
Programming Paradigm

- 基于智能算法，如神经网络，则通常首先收集与问题相关的数据，并进行打标，即标注中数据对应的正确类别。然后构建网络，将数据输入给网络，并根据一定的学习方法，让网络学习数据与标签的内在关系。当学习结果满足一定的条件后，再利用网络解决与学习时的输入数据类别一致的问题。

  With intelligent algorithms such as neural networks, the usual process begins by collecting data relevant to the problem and annotating it, aka, assigning correct categories to the samples. Then, a network is constructed and data is fed into the network, using specific learning methods to guide the network grasping the relationship between the data and their labels. Once the learning process meets certain criteria, the network is used to solve problems which must be consistent with the categories of the input data during the learning phase.



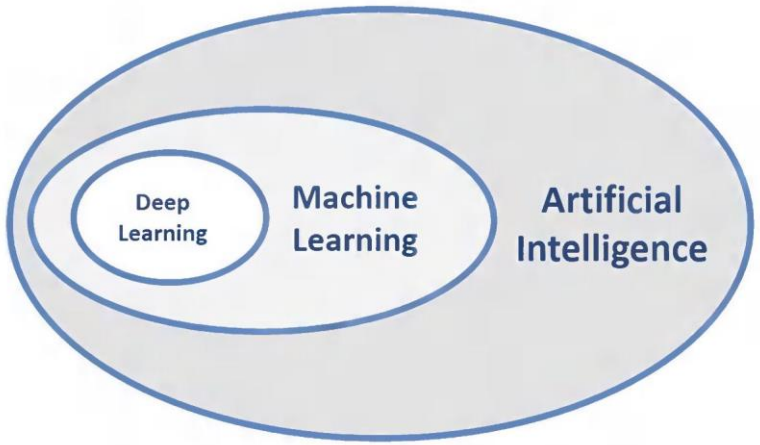
机器学习
Machine Learning

- 这种强调无需显式编程，从数据或经验中学习提高，达到解决同类问题的目的的方法，称为机器学习。传统机器学习较多地依赖概率统计方法，如贝叶斯方法，而依靠神经网络模型从数据中学习的方法称为深度学习。

  This approach, which emphasizes learning and improvement from data or experience without explicit programming to solve similar problems, is called machine learning. Traditional machine learning relies more on probability and statistical methods, such as Bayesian methods, while the approach of learning from data using neural network models is referred to as deep learning.

- 人工智能、机器学习与深度学习是三个既有联系又有区别的概念，其关系如右图所示：

  Artificial intelligence, machine learning, and deep learning are three concepts that are both connected and distinct. Their relationship is illustrated in the diagram on the right:



机器学习
Machine Learning

- 为了解决不同类型问题和学习场景的需求，帮助使用者根据可用数据的特征和期望的结果选择最适合的算法和方法，机器学习主要包括三种类型：

  To address different types of problems and learning scenarios, as well as help researchers and practitioners choose the most appropriate algorithms and methodologies based on the characteristics of the available data and the desired outcomes, machine learning is divided to three types:

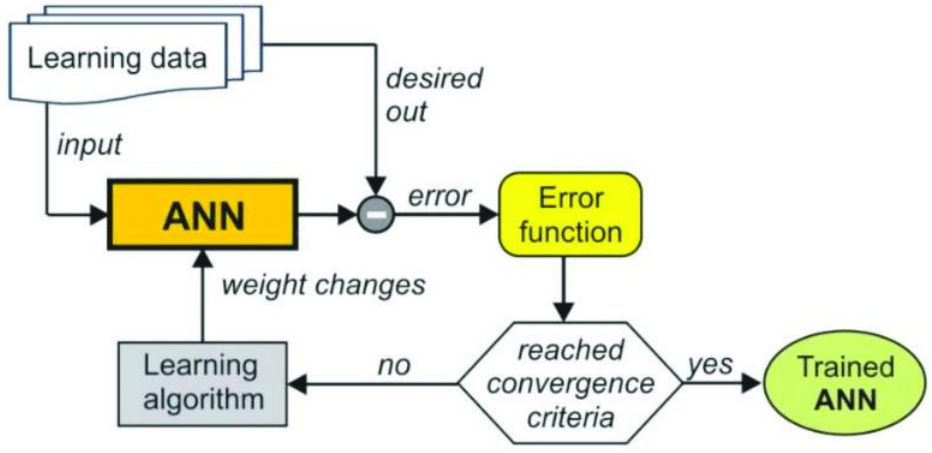
  - 监督学习（Supervised Learning）
  - 无监督学习（Unsupervised Learning）
  - 其他类型
    - 半监督学习（Semi-supervised Learning）
    - 强化学习（Reinforcement Learning）
- 由于深度学习是机器学习的子集，因此深度学习也适用于上述概念。

  As deep learning is a subset of machine learning, the above concept is also applicable to it.

机器学习
Machine Learning

- 监督学习是通过提供输入数据和标签引导计算机学习来完成的。例如，可以向机器提供带有相应标签（例如小猫）的图片，引导计算机学习小猫的内在特征，以便进行后续的泛化。之后，如果我们提供了另一只没有标签的小猫的图像，则机器将能够预测该图像就是小猫的图像。

Supervised learning is accomplished by guiding the computer through the provision of input data and labels. For example, images with corresponding labels (such as 'cat') can be provided to the machine to guide it in learning the intrinsic features of cats for subsequent generalization. Later, if we provide another unlabelled cat image, the machine will be able to predict that the image is that of a cat.



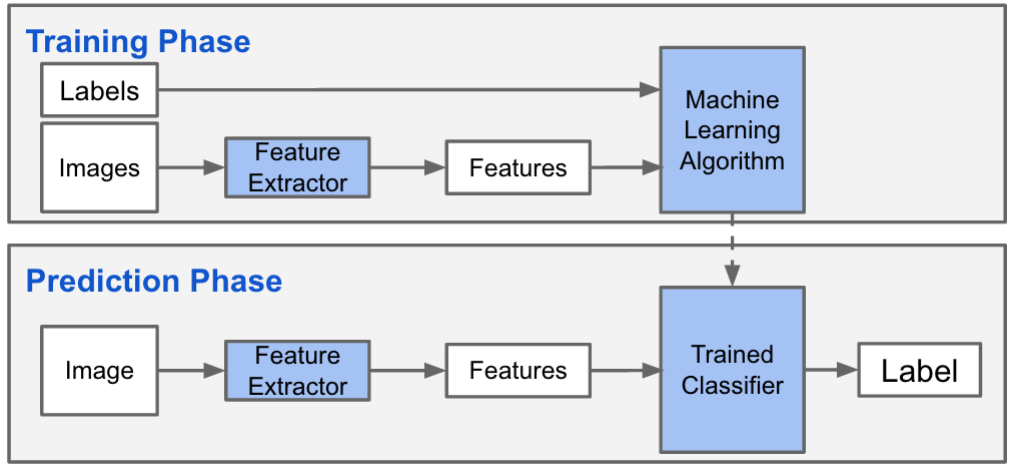
机器学习
Machine Learning

- 监督学习的特性决定了监督学习通常包括两个阶段，训练阶段和测试阶段。在训练阶段，模型学习输入与期望输出之间的映射或关系。在测试阶段，模型在新的、未见过的数据上进行预测。

  The characteristics of supervised learning determine that it typically involves two stages: the training stage and the testing stage. During the training stage, the model learns the mapping or relationship between inputs and expected outputs. In the testing stage, the model makes predictions on new, unseen data.

- 基于监督学习的例子包括支持向量机（SVM），神经网络等。

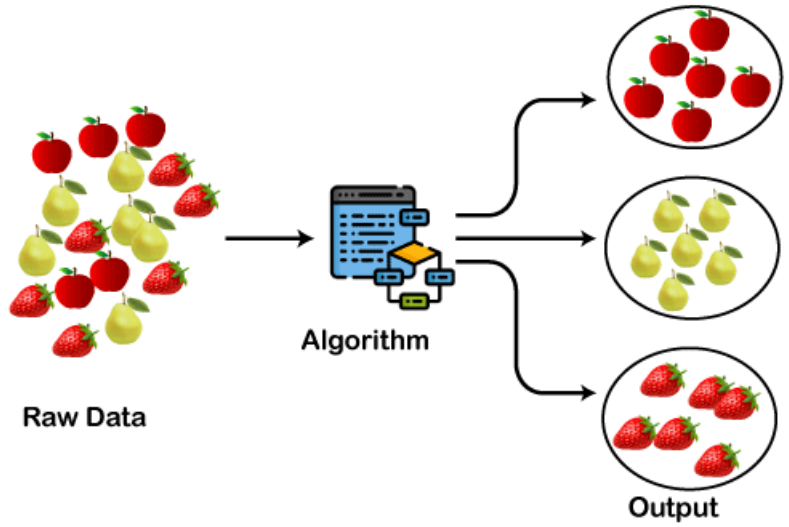
  Examples of supervised learning include Support Vector Machines (SVM), neural networks, and so on.

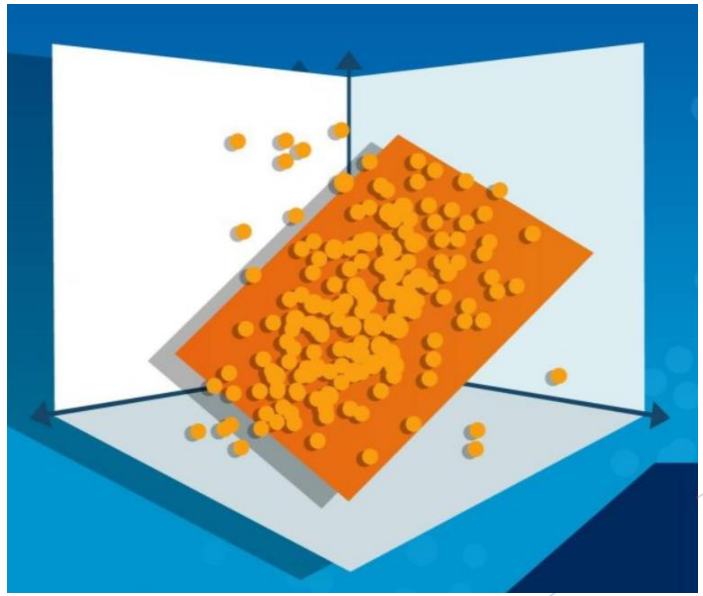


机器学习
Machine Learning

- 非监督学习或无监督学习是从不包含标签的数据集中得出推论的算法，主要包括聚类分析和降维等方法。

  Unsupervised learning is an algorithm that draws inferences from a dataset that does not contain labels, primarily including methods such as clustering analysis and dimensionality reduction.





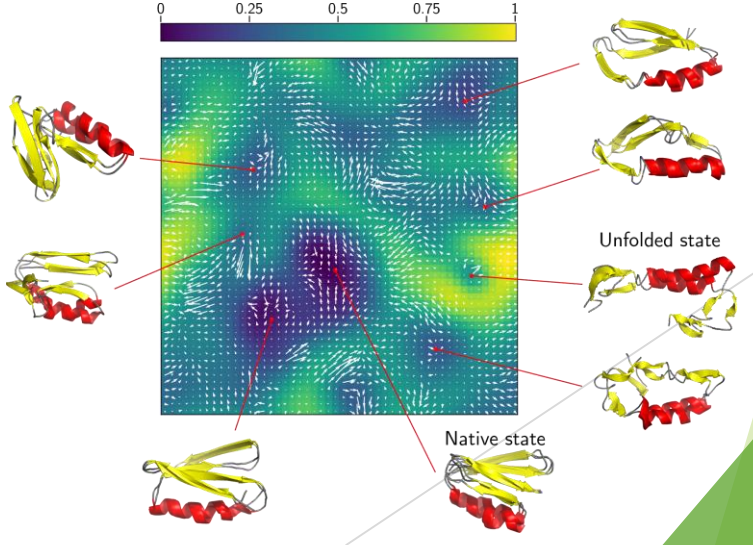
机器学习
Machine Learning

- 聚类分析主要用于根据数据的内在属性分组；降维主要用于减小特征的维度，创建更简明的学习表示。这两种方法均可用于如数据的可视化。注意非监督学习得到的结果可能并不准确或唯一，因此要求待解决的问题具有一定的容错性。

  Clustering is primarily for grouping data based on its inherent attributes, while dimensionality reduction is mainly used to decrease the dimensions of features, creating more concise learning representation. Both methods can be employed for tasks like data visualization. Notably, the results obtained from unsupervised learning are not necessarily accurate or unique. Therefore, it is essential for the problems to be solved are tolerable to some randomness.

- 基于监督学习的例子包括K均值聚类，主成分分析，自组织映射等。

  Examples of supervised learning include K-means clustering, principal component analysis, self-organizing maps, and so on.



强化学习
Reinforcement Learning

- 强化学习是一种非常重要的机器学习范式，因此往往独立来讲。

  Reinforcement learning is such an important machine learning paradigm and is often discussed independently.

- 上世纪50年代，学者James Old与Peter Milner决定将电极植入小鼠的大脑，进行相关研究。他们设计的实验装置可以诱使小鼠无意地按下推杆，让它们的大脑接受轻微的电刺激。Olds和Milner发现当把电极置于位于胼胝体前端下方的中隔区时，老鼠会反复按压控制杆以接收刺激。他们发现实验中的一只老鼠在12小时内按了7500次杠杆去电刺激该区域。

  In the 1950s, the scholars James Old and Peter Milner decided to implant electrodes into the brains of mice for their research. The experimental setup they designed could induce mice to unintentionally press a lever, causing their brains to receive mild electrical stimulation. Olds and Milner found that when the electrodes were placed in the septal area just below the front of the corpus callosum, the mice would repeatedly press the lever to receive stimulation. They observed that one mouse in the experiment pressed the lever 7500 times within 12 hours to receive stimulation in that area.

强化学习
Reinforcement Learning

- Olds和Milner的实验验证了大脑存在存在着某些结构，这些结构有调节个体体验有益经历的功能。实验中老鼠反复按杠杆来接收这些区域的刺激，这表明它们正在享受这种体验。随后的研究试图更彻底地绘制出这些“奖励区域”，丰富人们对奖励系统的更多更为深刻地理解。最终，人们认识到多巴胺及相应神经元在这种有益的大脑刺激过程中的作用。

The experiment conducted by Olds and Milner confirmed the existence of certain structures in the brain that regulate an individual's experience of rewarding activities. In the experiment, mice repeatedly pressed a lever to receive stimulation in these areas, indicating that they were enjoying the experience. Subsequent research aimed to more comprehensively map these "reward regions," enhancing people's deeper understanding of the reward system. Ultimately, it was recognized that dopamine and corresponding neurons play a crucial role in this beneficial brain stimulation process.

强化学习
Reinforcement Learning

- 后来在遵循人体实验道德伦理前提下，在人类被试上的实验亦验证了与小鼠同样的行为。而对行为的研究，形成了奖励系统的有关知识。目前，我们认识到这些自愿行为的动机，是因为个人认为此行为有益或体验到了愉快。同时，我们认识到人们关于环境和人类自身的主要知识来源，很大一部分是通过与环境的交互进行学习来获得的。我们意识到环境如何对我们的行为做出的反应，并且我们试图通过我们的行为来影响所发生的事情。而促动这种行为发生的，正是奖励系统起作用的原因。强化学习正是受此启发而建立的计算范式。
- Later, under the premise of adhering to ethics in human experiments, experiments on human subjects also validated behaviours similar to those observed in mice. The research on behavior contributed to the knowledge about the reward system. Currently, we recognize that the motivation behind voluntary actions is often rooted in individuals perceiving the behavior as beneficial or experiencing pleasure. Simultaneously, we understand that a significant portion of our primary knowledge about the environment and human nature is acquired through interactive learning with our surroundings. We are aware of how the environment responds to our actions, and we attempt to influence outcomes through our behaviours. The reason behind driving such behaviours is the functioning of the reward system. Reinforcement learning is established as a computational paradigm inspired by this.

强化学习
Reinforcement Learning

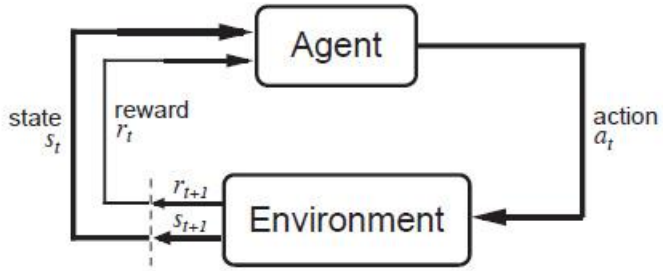
- 强化学习是智能体通过与环境进行交互，即执行某些操作并观察从这些操作中获得的最佳奖励来学习如何响应环境中的特定状态的策略的方式。强化学习的一个很重要的议题就是策略的表示。由于在智能体与环境交互的过程中，环境状态是一个巨大的变量，学习状态空间与在策略驱动下采取动作获得最佳奖励是一个困难的事情。而神经网络的应用有效地解决了这个难题。

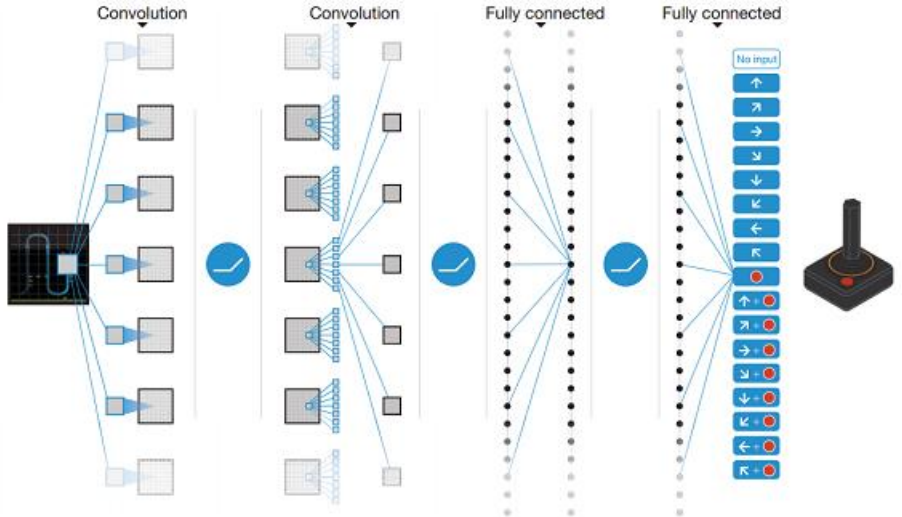
Reinforcement learning is a method in which an intelligent agent learns how to respond to specific states in the environment by interacting with it, executing certain actions, and observing the best rewards obtained from these actions. A crucial aspect of reinforcement learning lies in the representation of strategies. Due to the vast variability of environmental states during the interaction between the intelligent agent and the environment, learning the state space and achieving optimal rewards through strategy-driven actions pose a significant challenge. The application of neural networks effectively addresses this challenge.

强化学习
Reinforcement Learning

- 强化学习基本思路是通过试错方式，学习从环境状态到动作的映射，以使动作从环境中获得的累积奖励最大化；其相关算法主要包括Q学习算法，动作器-评判器算法，近端策略优化算法等等。

The fundamental idea of reinforcement learning is to learn the mapping from environmental states to actions through a trial-and-error process, aiming to maximize the cumulative rewards obtained from the environment. Related algorithms include Q-learning, actor-critic algorithms, proximal policy optimization algorithms, and so on.





机器学习要素
Machine Learning Elements

- 在人们对机器学习的研究中，人们认识到利用机器学习方法解决问题时，涉及到以下组成要素：

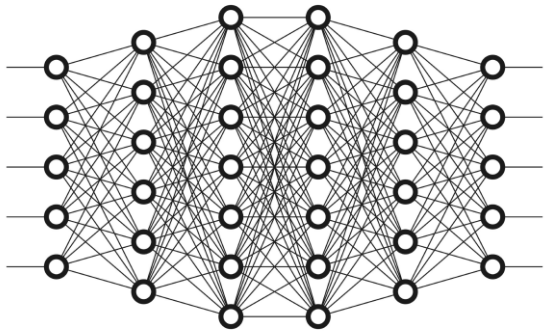
  In the study of machine learning, people recognize that when utilizing machine learning methods to solve problems, the following components are involved:

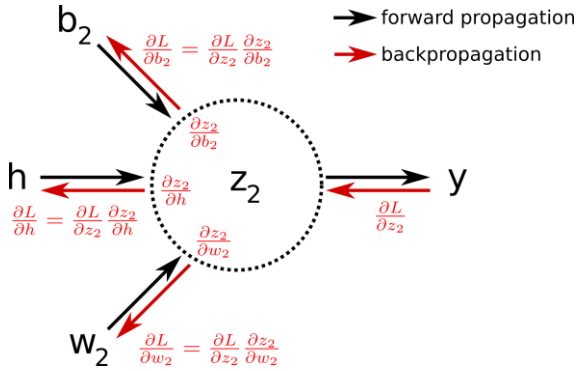
数据	模型输入，数据的特征取决于问题领域	Data	The input to model, and the features of the data depend on the problem domain.
模型	解决问题所采用的结构或算法	Model	The structure or algorithm adopted to solve the problem.
目标或损失函数	由机器学习的范式而定，如果是监督学习，则一般有显示的损失函数，若是非监督学习，损失内蕴于数据或样本本身	Loss Function	Determined by the paradigm of machine learning. Generally an explicit loss function exists for supervised learning; Inherent loss in the data or samples themselves for unsupervised learning.
学习方法	为使模型达到目标采取行动时所依照的法则	Learning Algorithm	The principles followed when taking actions to achieve the model's objectives.

机器学习要素
Machine Learning Elements

- 以神经网络为例，神经网络本身构成了对问题进行建模的模型；损失函数则依据是分类问题或回归问题，通常采用对数损失函数或平方损失函数；学习方法即反向传播算法。

  Taking neural networks as an example, the neural network itself constitutes the model for modeling the problem; the loss function depends on whether it is a classification or regression problem, usually employing logarithmic loss or mean square error loss; the learning method is the backpropagation algorithm.



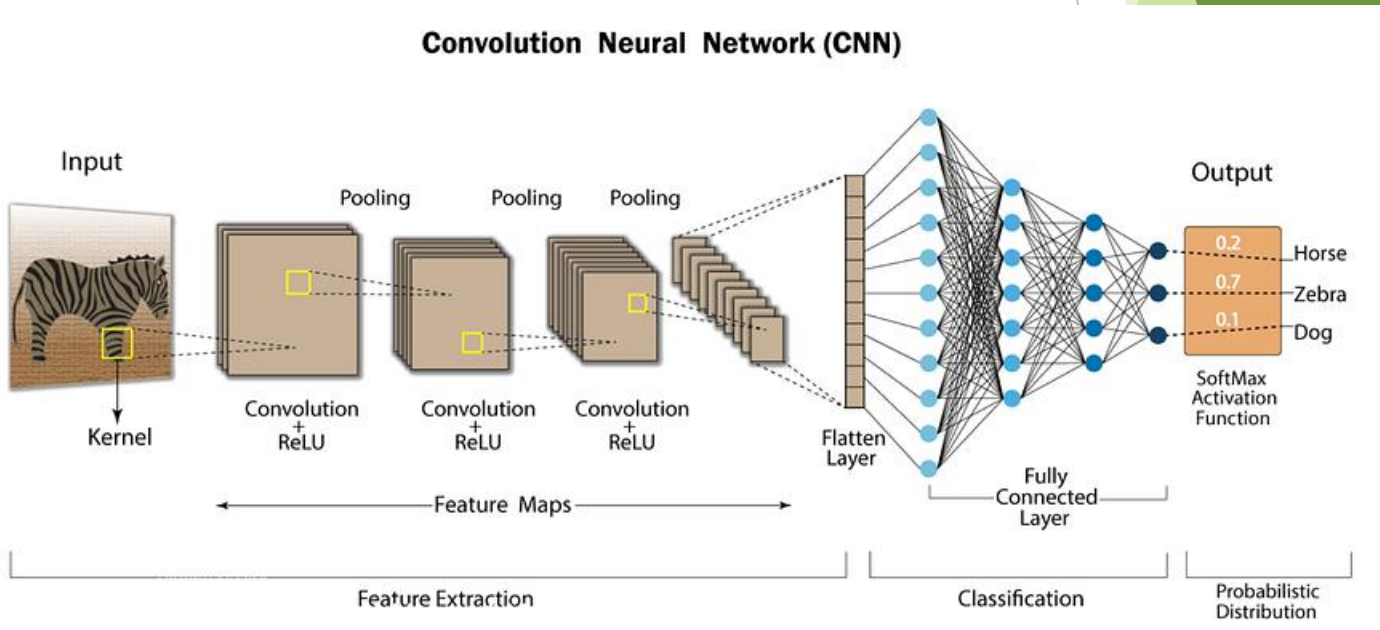


$$MSE = \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}$$

网络分类
Network Types

- 当用神经网络解决具体问题时，我们会根据数据的特征与任务的性质，选择合适的神经网络。如果数据的维度较小，且特征独立程度较高，我们会选择全连接网络；如果类似图片这样的数据，元素之间具有较高的空间相关性，我们会选择卷积神经网络。

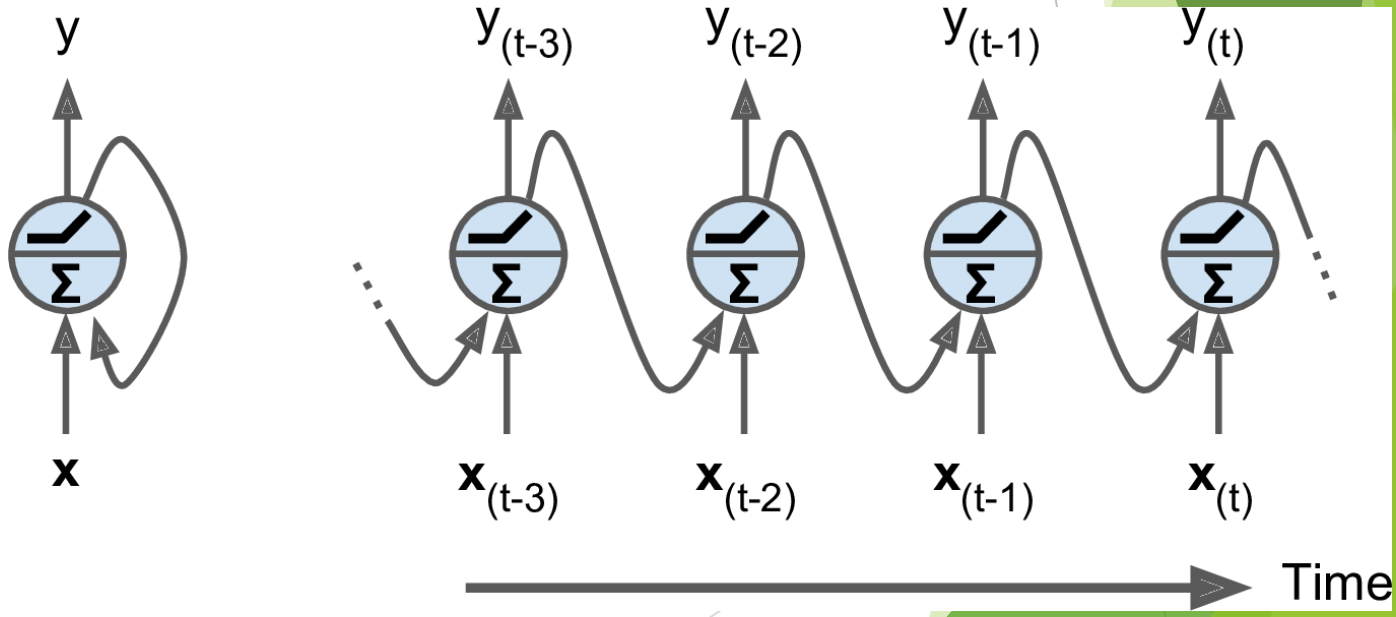
When solving specific problems with neural networks, we choose appropriate neural network architectures based on the characteristics of the data and the nature of the task. If the data has a low dimensionality and features are highly independent, we opt for fully connected networks. On the other hand, for data like images, where elements exhibit high spatial correlation, we choose convolutional neural networks.



网络分类
Network Types

- 但对于一些时序数据，包括文本、语言等，通常我们会选择用循环神经网络来处理，以便挖掘数据在时间或空间维度上的相关性。与全连接网络、卷积神经网络相比，循环神经网络的特点是具有循环或反馈结构，使得当前时刻的输出成为下一时刻的输入。

But for time-series data, including text, language, etc., we typically choose recurrent neural networks for processing them. This enables the exploration of correlations in the data along the time or spatial dimensions. In contrast to fully connected networks and convolutional neural networks, recurrent neural networks are characterized by a recurrent or feedback structure, allowing the output at the current time step to be fed together with the input into network for the next time step.



总结
Summary

- 神经网络的运用在各种应用中取得了显著的成就。例如，卷积神经网络在图像识别、目标检测和分割方面取得了卓越的成就。循环神经网络在时序数据任务中表现出色，如语音识别和语言建模。在架构、训练技术和跨学科应用的不断创新下，神经网络持续展现在推动技术发展和解决实际挑战方面的影响。

  The utilization of neural networks has led to significant achievements across various applications. For example, Convolutional Neural Networks (CNNs) have excelled in image recognition, object detection, and segmentation; Recurrent Neural Networks (RNNs) have proven effective in sequential data tasks such as speech recognition and language modeling. Meanwhile, The continuous innovation in architectures, training techniques, and the exploration of interdisciplinary applications showcase the ongoing impact of neural networks in advancing technology and solving real-world challenges.