Modeling & Computation

Shusen Wang

Learning from Data

Future Data

Model

Predict

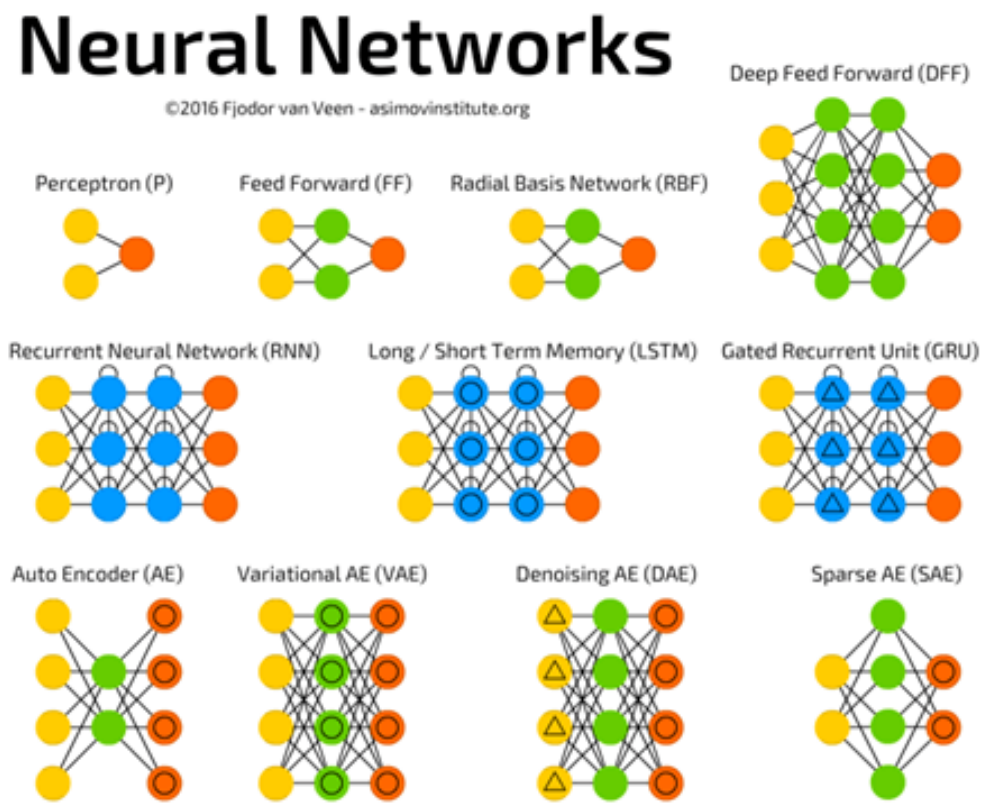
"car"

Train

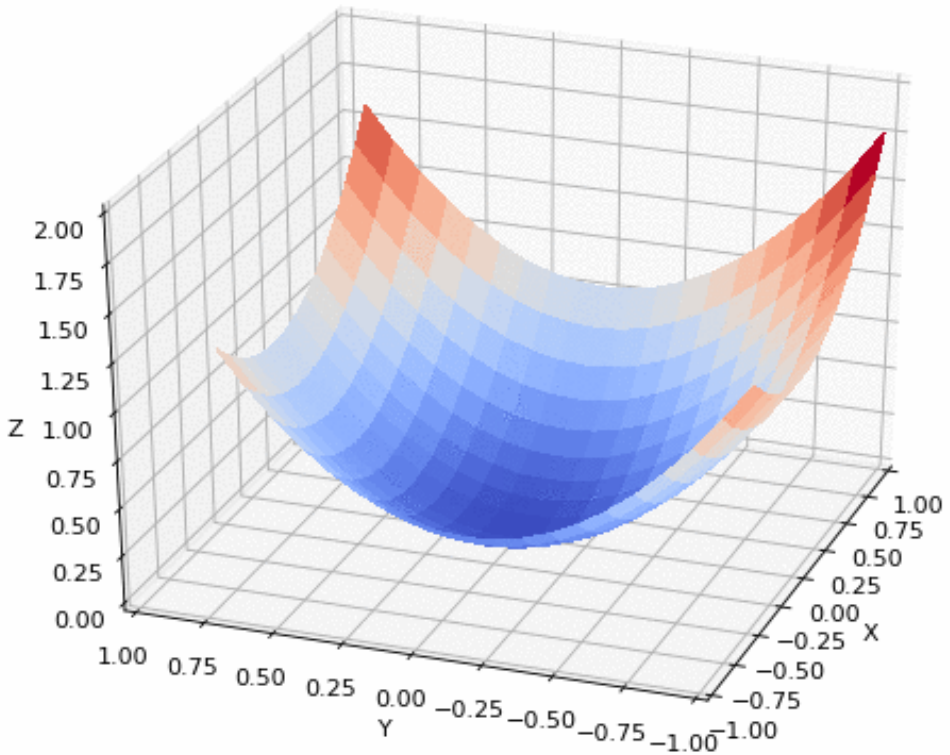
Past Data
(perhaps with **labels**)

Machine Learning in Practice

Modeling



Computation



Modeling

Linear Models

- Feature vector: $\mathbf{x} \in \mathbb{R}^d$ (e.g., features of a house).
- Prediction: $f(\mathbf{x}) = \mathbf{x}^T \mathbf{w}$ (e.g., housing price).

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  - $f(\mathbf{x}) = w_1 x_1 + w_2 x_2 + \cdots + w_d x_d$
  - $w_1, w_2, \cdots, w_d$: weights
  - x_1: # of bedrooms
  - x_2: # of bathroom
  - x_3: square feet
  - …

Linear Models

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Question: How to find $\mathbf{w}$?

Features of a House

$\mathbf{x} \in \mathbb{R}^d$

Price = $0.5M

Prediction:

$f(\mathbf{x}) = \mathbf{x}^T \mathbf{w}$

Linear Models

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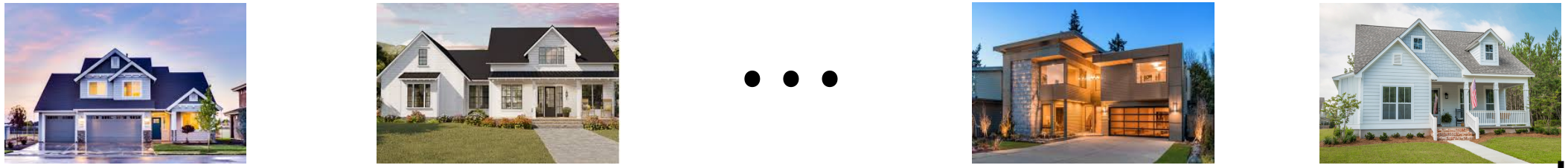
- Training targets: $y_1, \cdots, y_n \in \mathbb{R}$.



totally n houses

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- Loss function: $L(\mathbf{w}) = \frac{1}{n} \sum_{i=1}^{n} \left(\mathbf{x}_i^T \mathbf{w} - y_i \right)^2$.
- Least squares regression: $\mathbf{w}^\star = \min_{\mathbf{w}} L(\mathbf{w})$.

Linear Models Are Not Expressive

Example: Given a person's photo, predict her/his age.

Photo (features)

Age = 36

Linear Models Are Not Expressive

线性模型具有 不可解释性

Example: Given a person's photo, predict her/his age.

Photo (features)

Age = 36

Question: Can we use linear regression?

- Linear regression assumes the target is a weighted average of every pixel in the photo.
- Linear regression works poorly for age prediction.

线性回归 年龄预测 效果不佳

Traditional Approaches

SIFT Feature

HOG Feature

LBP Feature

Traditional Approaches

SIFT Feature

HOG Feature

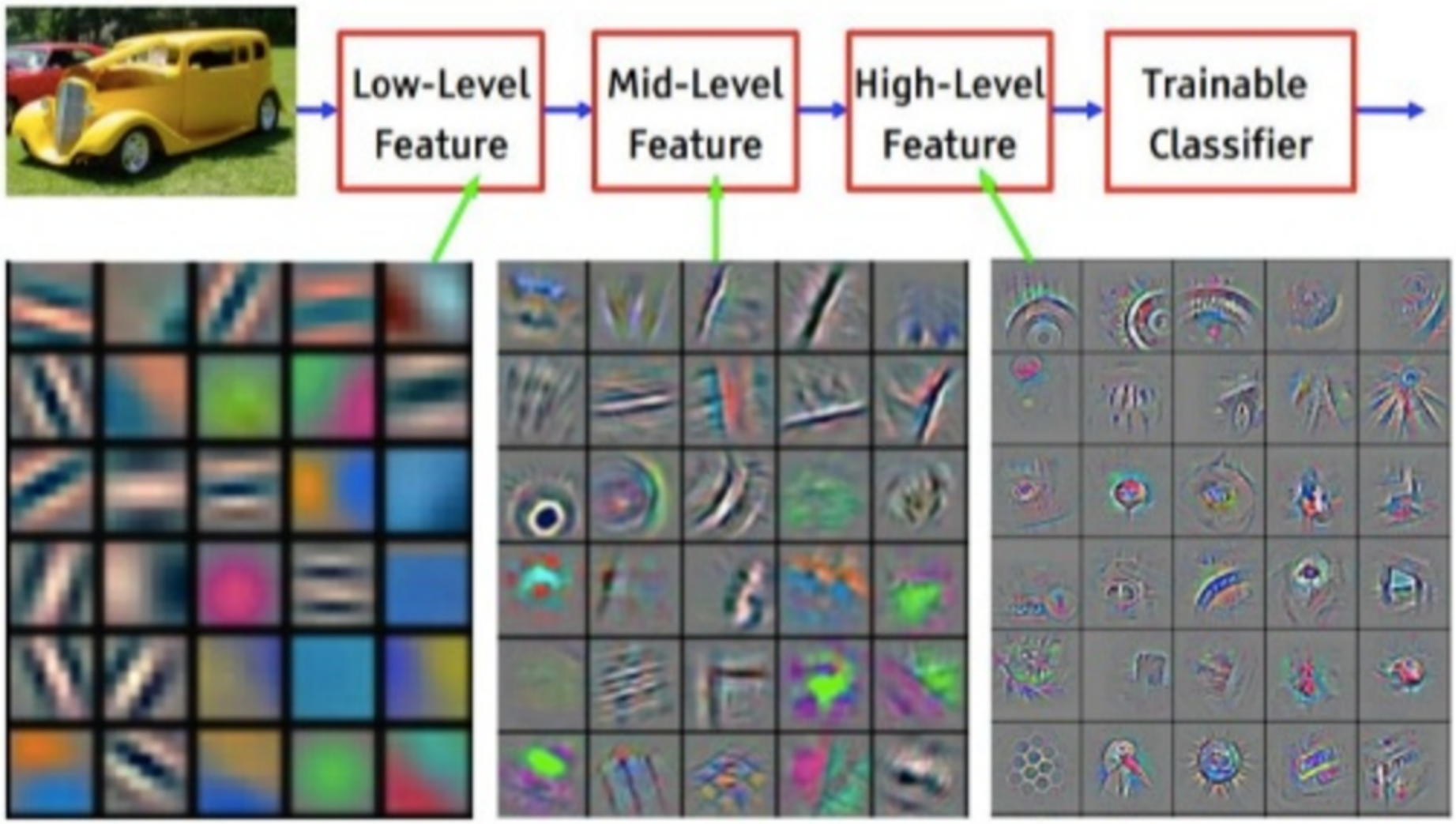
LBP Feature

(Local Binary Pattern)，局部二值模式

Linear Model

“dog”

Convolutional Neural Networks (CNNs)

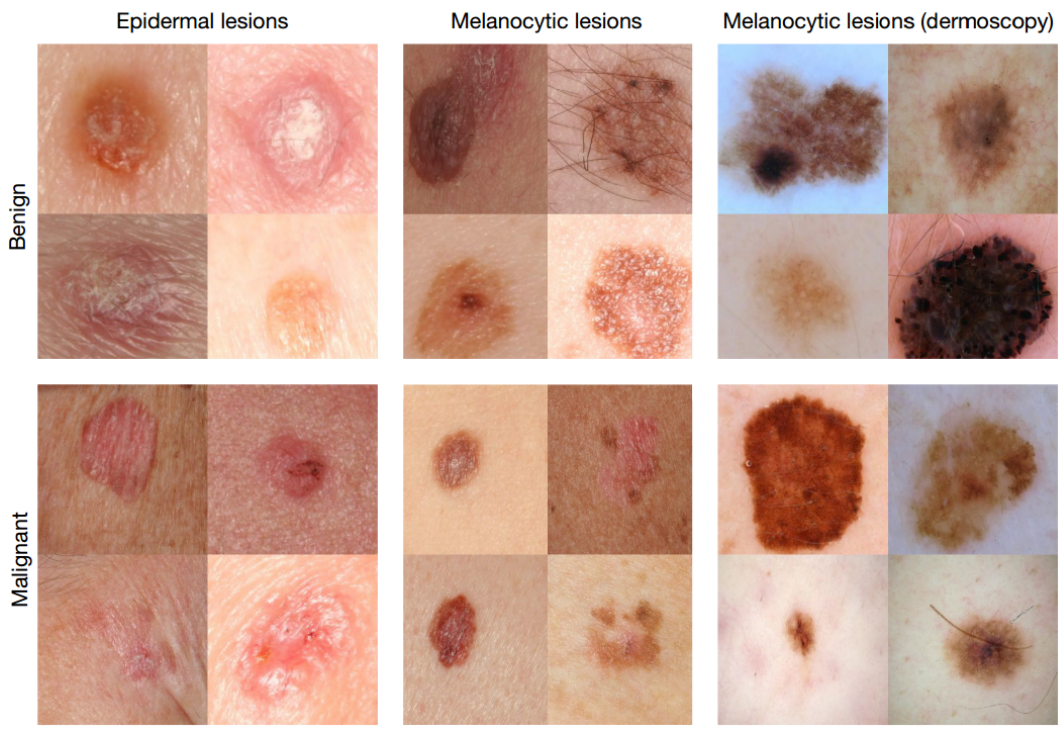


Applications of CNNs

- CNNs are suitable for image data.
- CNNs convert images to effective representations. (Feature extraction.)

- Applications:
  - Image/video recognition.
  - Face recognition.
  - Image generation.
  - …

Applications of CNNs: Medical Diagnosis



皮肤癌 诊断

Example: Skin cancer diagnosis

- Input: an image.
- Outputs:
  - Is it skin cancer?
  - Benign or malignant?
- The same accuracy as human experts.

Reference

[1] Esteva et al. Dermatologist-level classification of skin cancer with deep neural networks. *Nature*, 2017.

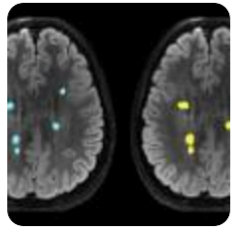
Applications of CNNs: Medical Diagnosis

Healthcare IT News

Australia's SNAC develops AI tools to improve brain scan analysis

... algorithms using the NVIDIA Clara suite of medical imaging tools, as well ... SNAC is building its deep learning algorithms using the PyTorch ...

10 hours ago

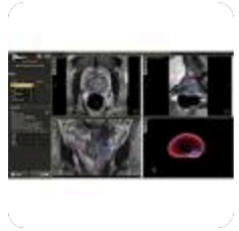


Imaging Technology News (press release) (blog)

Improved Imaging Technique Could Increase Chances of Prostate Cancer Survival

“Imaging has become an essential component of modern medicine,” said ... Using a deep learning approach, Yan plans to simplify the process.

20 hours ago



Data Center Frontier (blog)

Startups Target AI Opportunities to Disrupt Medical Imaging

AI, or more specifically machine learning and deep learning algorithms, are learning how to analyze the images produced by radiology scans.

2 weeks ago

Xtelligent Healthcare Media

Deep Learning Tool Detects Cancer in Radiology Reports

Human reviewers analyzed the imaging text reports and noted whether cancer ... The team then used these reports to train a deep learning algorithm to ... Amazon's Comprehend Medical, an advanced machine

3 weeks ago

Medical Xpress

Deep learning model detects diabetic eye diseases accurately

The deep learning model identified referable diabetic retinopathy ... Currently, retinal imaging is the most widely used method for screening and detecting retinopathy, and medical experts evaluate the severity and the

2 days ago

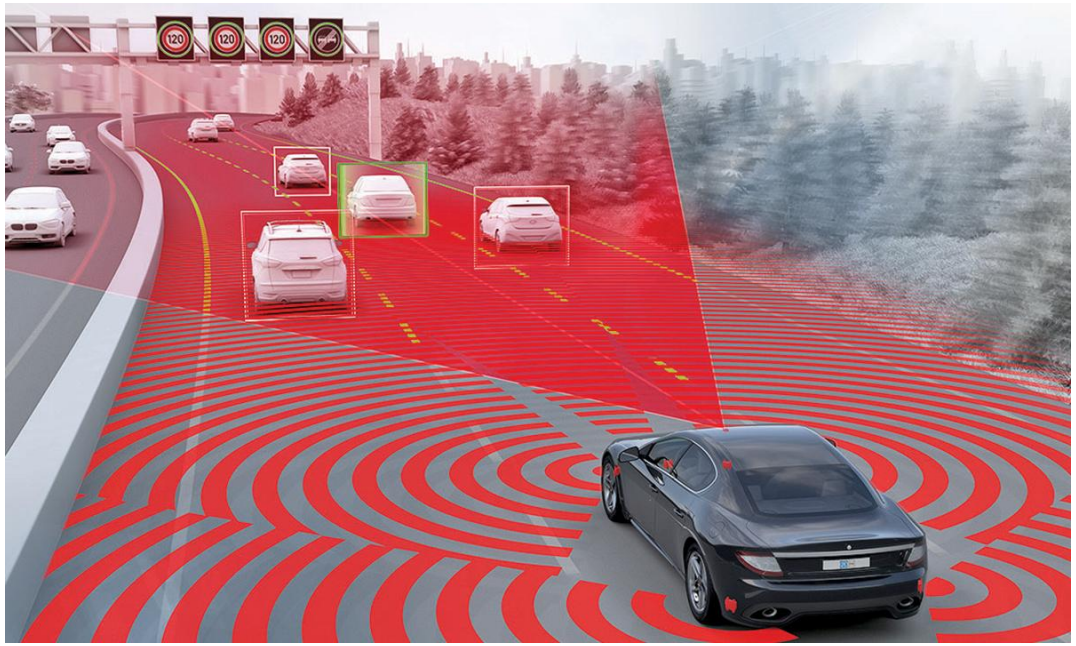
Yahoo Finance

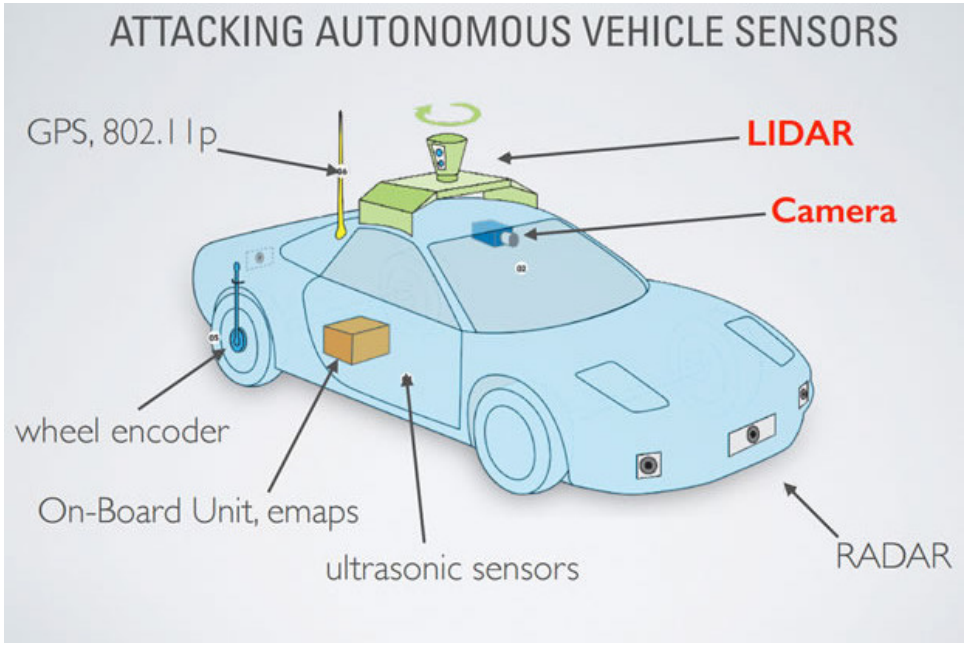
Progenics Pharmaceuticals Announces Collaboration with Veterans Affairs on the AI Research Program for Medical Image Analysis

The collaboration with VA Greater Los Angeles Healthcare System is nation's first to validate deep learning algorithms in medical imaging of ...

4 weeks ago

Applications of CNNs: Self Driving Cars



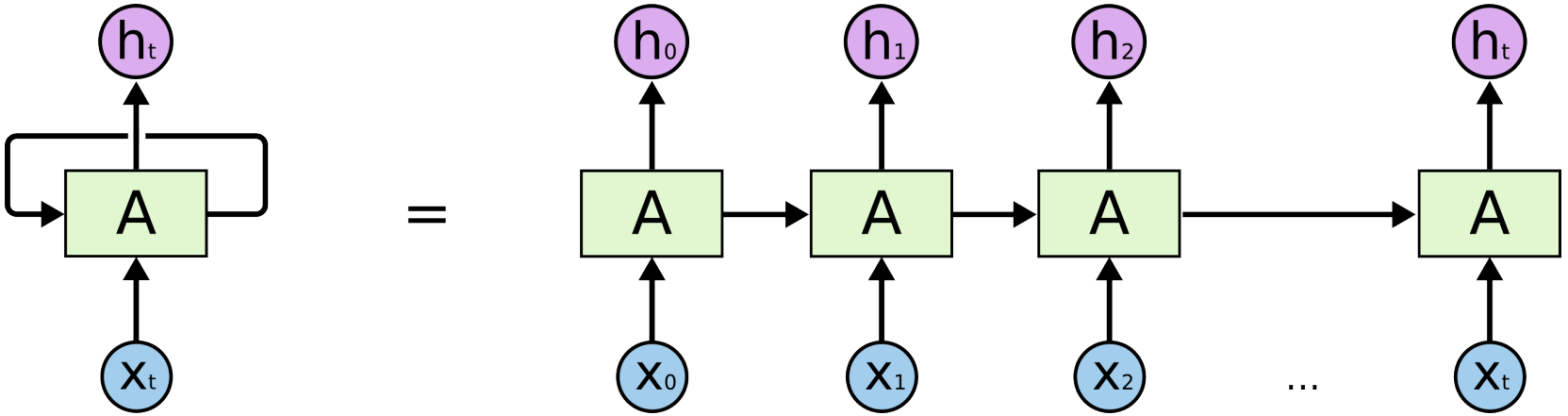


- CNNs play an import role in self driving cars.
  - Understand images taken by the cameras. 图像理解 （摄像机拍摄的图片）
  - Recognize signs, cars, pedestrians, and obstacles. 识别标志、汽车、行人和障碍物
- CNN is not everything; self-driving car is a sophisticated system.

自动驾驶汽车是一个复杂的系统

Recurrent Neural Networks (RNNs)

- RNNs naturally fit sequence data, e.g.,
  - time series data,
  - text data,
  - speech data…



Applications of RNNs: Machine Translation

机器翻译

Applications of RNNs: Machine Translation

Chinese - detected ⇄ English

机器翻译让沟通交流变得更容易

Jīqì fānyì ràng gōutōng jiāoliú biàn dé gèng róngyì

Machine translation makes communication easier

Applications of RNNs: Speech Recognition

语音识别

amazon alexa

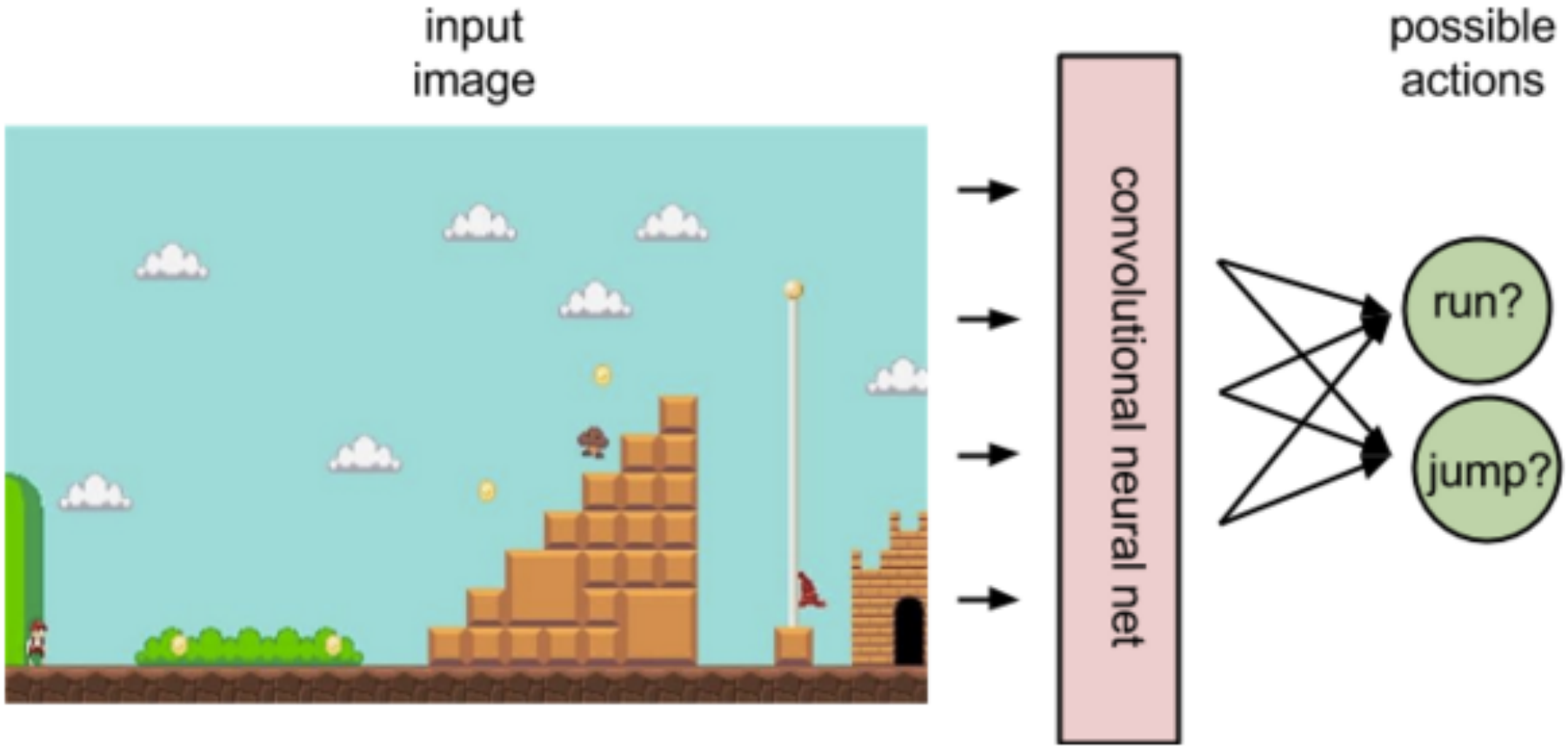
Hey Siri

Deep Reinforcement Learning (DFL)

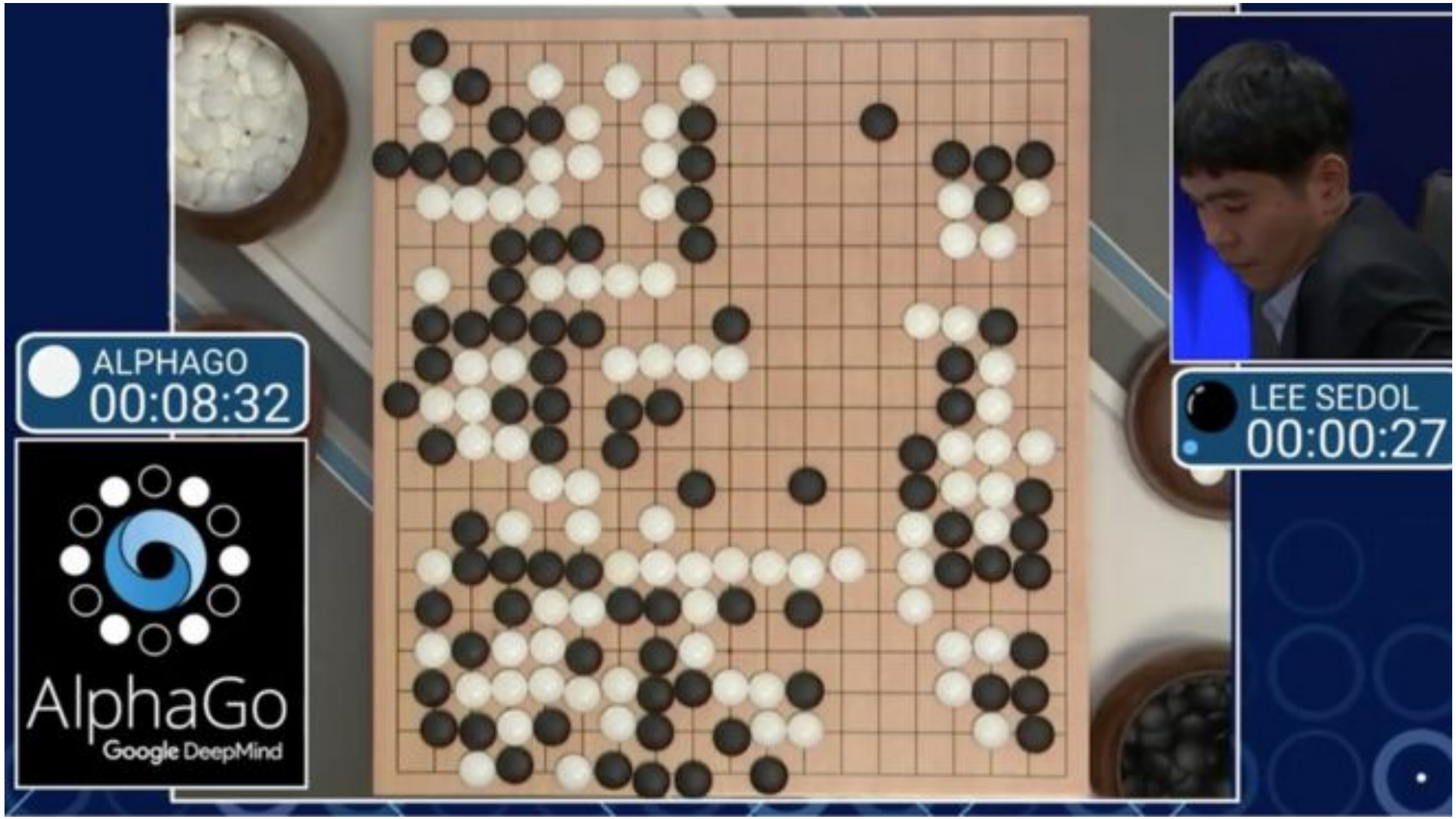
深度强化学习

- DFL has applications in robotics, video game, and finance.

深度 强化学习 在机器人技术、电子游戏和金融等方面都有应用。



Applications of DRL: Games



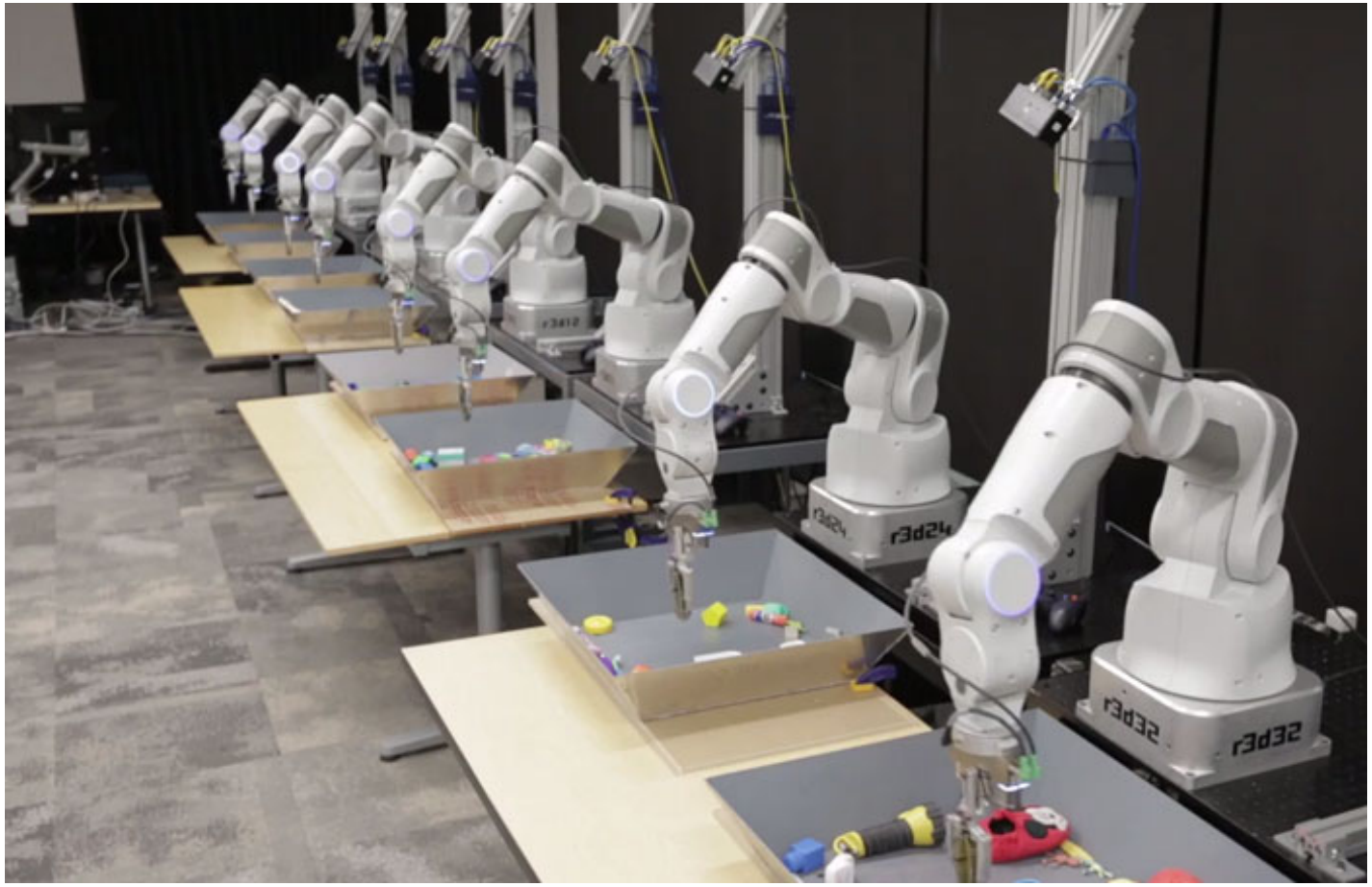
Applications of DRL: Robotics

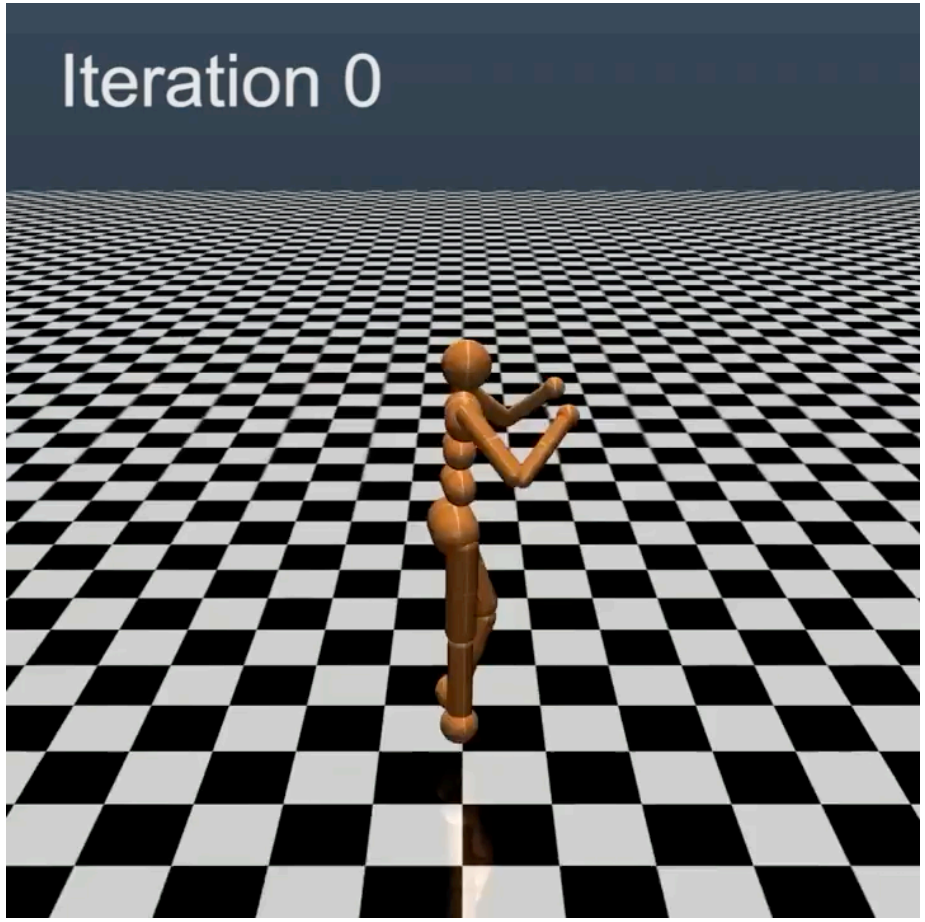
Control Theory v.s. DRL

Boston Dynamics' Atlas

Applications of DRL: Robotics

Control Theory v.s. DRL





What we have learned so far…

- **ML tasks**: regression, classification, …
- **ML models**: linear models, CNNs, RNNs, …

Example: least squares regression model

- Loss function: $L(\mathbf{w}) = \frac{1}{n}\sum_{i=1}^{n}\left(\mathbf{x}_i^T\mathbf{w} - y_i\right)^2$.
- Optimization: $\mathbf{w}^\star = \min_{\mathbf{w}} L(\mathbf{w})$.

- How to solve the model?

Computations

Computational Methods

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- **Computations**: solve the model using numerical algorithms, e.g., gradient descent (GD) or stochastic descent (SGD).

Gradient Descent

Example: least squares regression model

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Gradient: $\frac{\partial L}{\partial \mathbf{w}}$

- $\mathbf{w}$ is a d-dimensional vector.
- $L(\mathbf{w})$ is a scalar.
- Thus $\frac{\partial L}{\partial \mathbf{w}}$ is a d-dimensional vector.

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Gradient descent algorithm

- Randomly initialize $\mathbf{w}_0$.
- For $t = 0$ to T:
  - Gradient at $\mathbf{w}_t$: $\mathbf{g}_t = \frac{\partial L}{\partial \mathbf{w}}\Big|_{\mathbf{w}_t}$;
  - $\mathbf{w}_{t+1} = \mathbf{w}_t - \alpha\, \mathbf{g}_t$.

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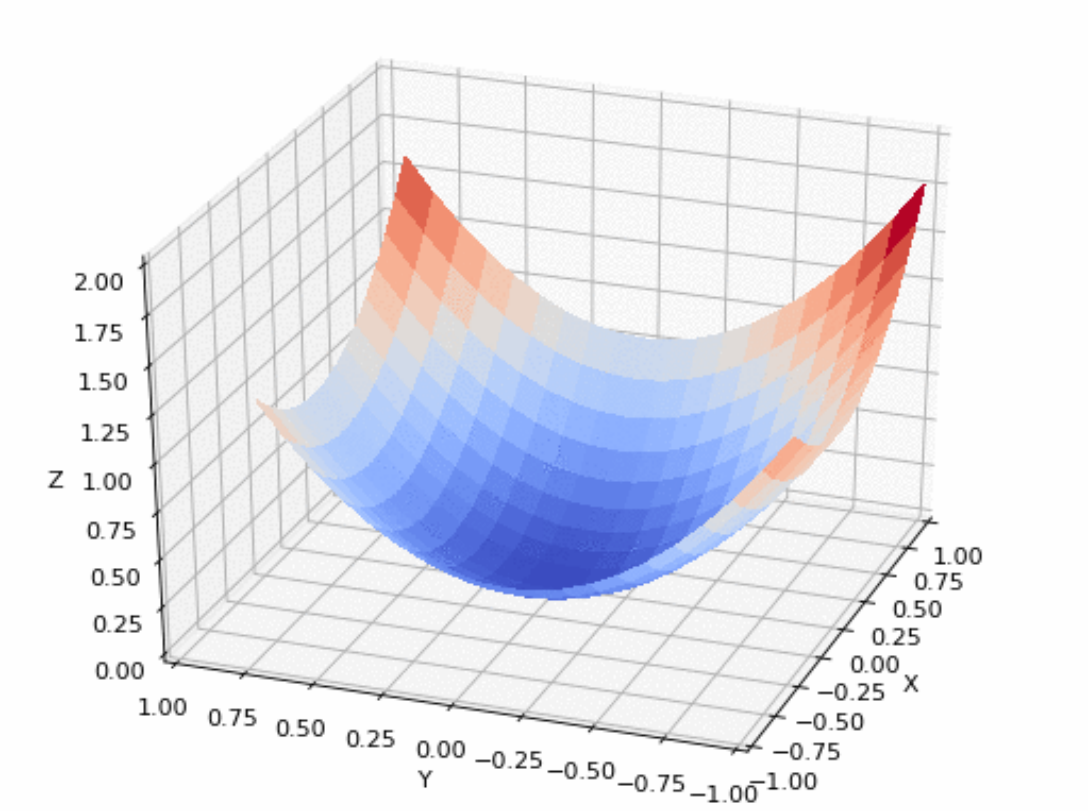

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Variants of Gradient Descent

- Stochastic gradient descent (SGD).
- SGD with momentum.
- RMSProp.
- ADAM…

Computational Challenges

- Big data: too many training samples.
  - ImageNet: 14 million 256×256 images.
- Big model: too many model parameters.
  - ResNet-50 (a very popular CNN architecture) has 25 million parameters.

2500万个参数

Computational Challenges

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- Big data + big model bring computational challenges.
- Training ResNet-50 on ImageNet using a single GPU takes around 14 days.

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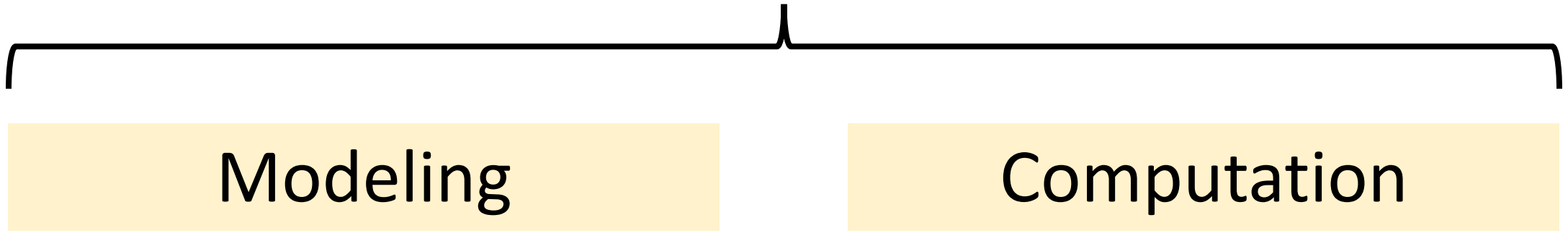
➔ Efficient algorithms and software systems are necessary.

高效的算法和软件系统是必要的

Machine Learning in Practice



Machine Learning in Practice

Modeling

Computation

- The model that fits the data and problem.
- Decide the network structures, activation functions, loss functions, etc.
- Improve the prediction accuracy.
  - Experience in ML models.
  - Understanding of the problem and data.

适合数据和问题的模型。

决定网络结构、激活功能、损失功能等

提高预测精度。

在ML模型方面的经验。

了解问题和数据

Machine Learning in Practice

Modeling

Computation

- Design or apply efficient algorithms. 设计或应用有效的算法
- Implement the algorithm using systems like TensorFlow, Hadoop, etc.

Machine Learning in Practice

Modeling

Computation

- Design or apply efficient algorithms.
- Implement the algorithm using systems like TensorFlow, Hadoop, etc.
- Optimize your code.
  - Experience in algorithms.
  - Experience in systems.