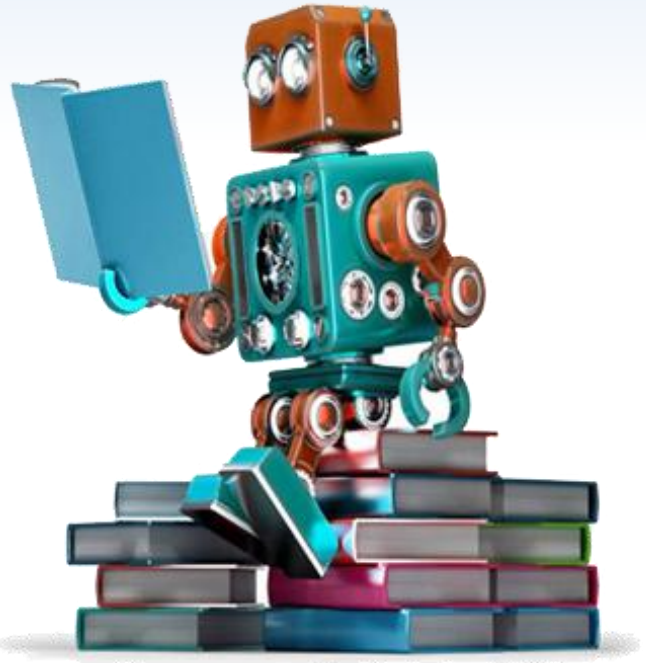
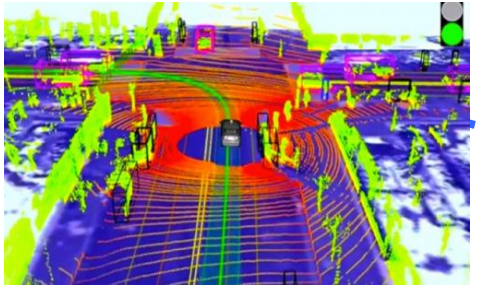
西北工业大学
NORTHWESTERN POLYTECHNICAL UNIVERSITY

机器学习
Machine Learning

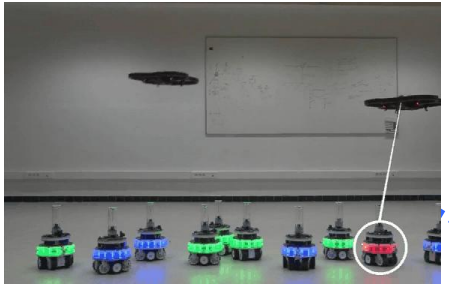
布树辉

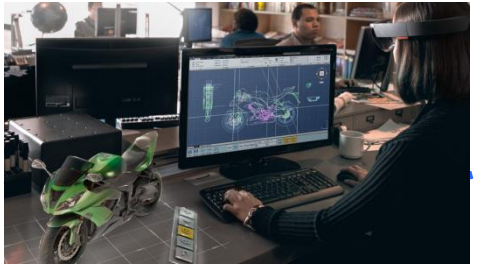


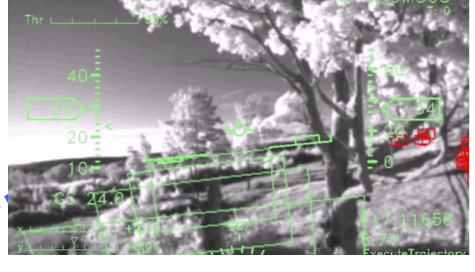
Future?



AI



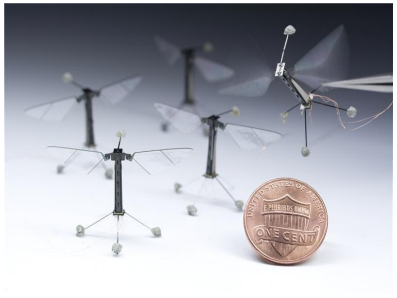




UAV

- Small, cheap
- No pilot
- Convenient
- Strong survivability

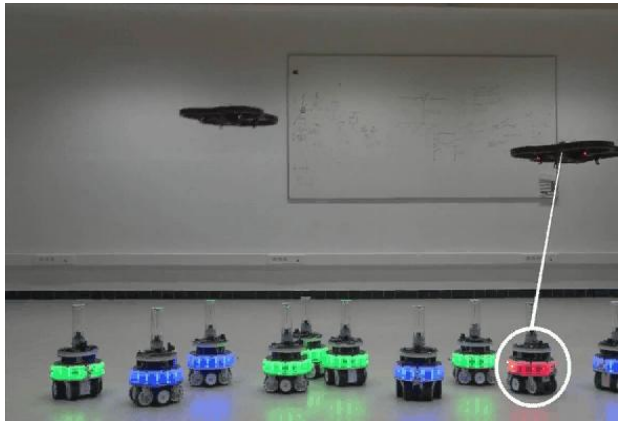
- Aerial photograph
- Attack
- Air platform
- General aviation

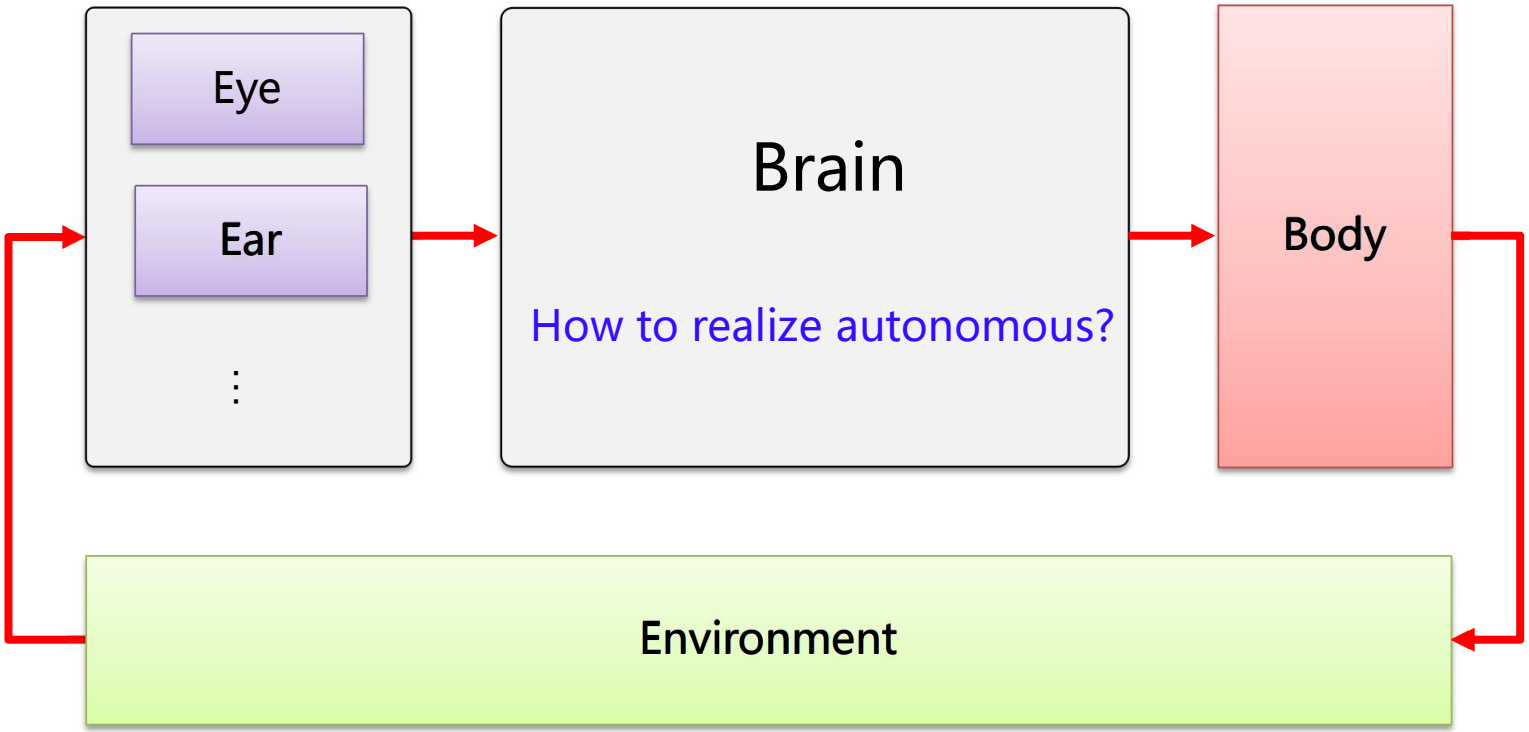



UAV - Autonomous

Remote Control → Heavy workload
Professional training
Difficult to be cluster → Autonomous



How to Realize Autonomous?



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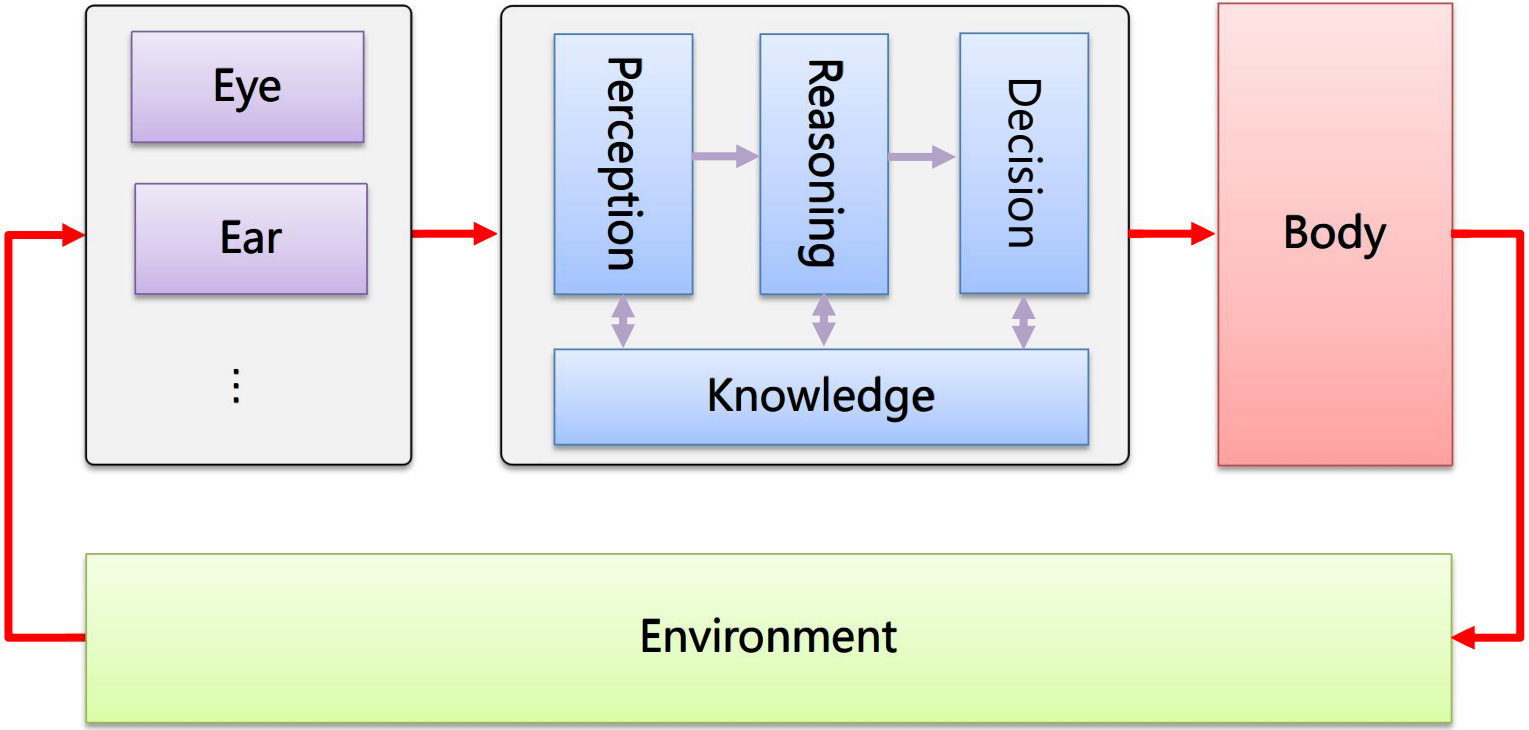
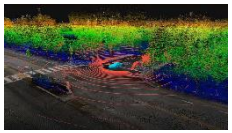
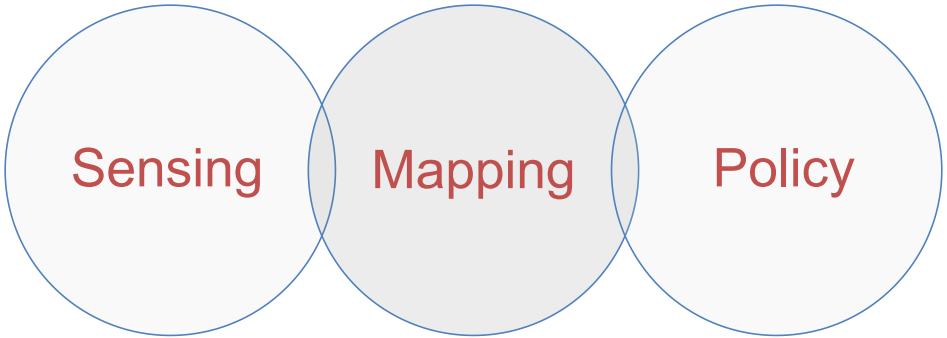


New Challenges

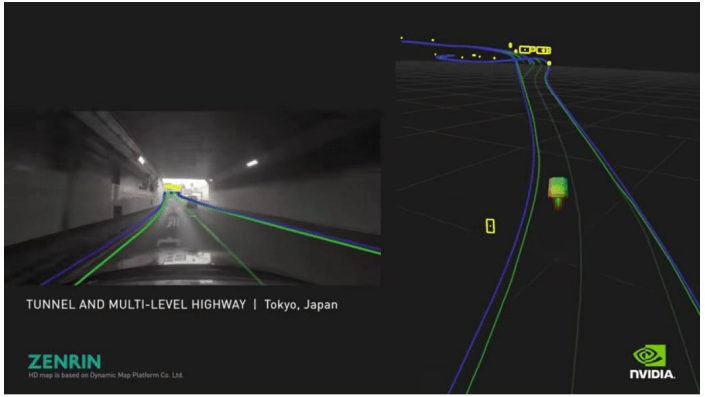



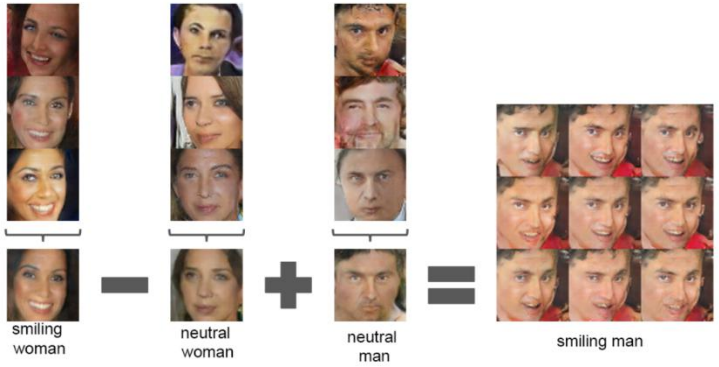



- Multi-type sensors: IMU, GPS, Image, LiDAR, RADAR …
- High quality and real-time speed required
- Reasoning and knowledge are important for realizing strong AI

Applications

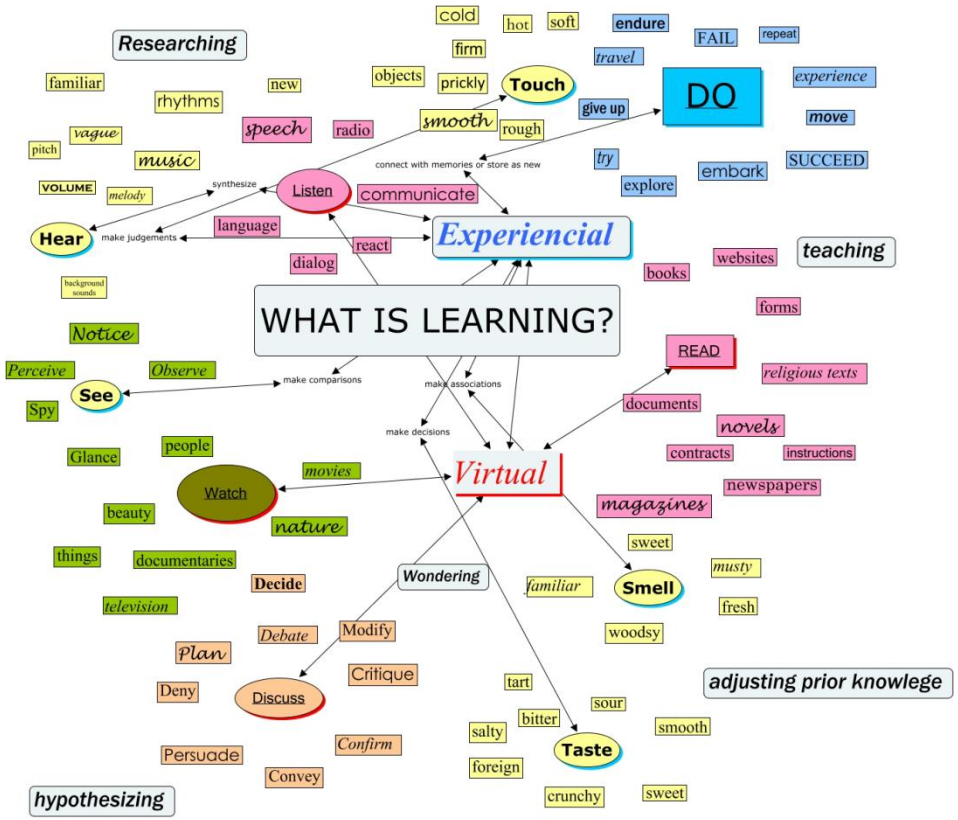
Applications





How to Achieve Intelligence?

How to Achieve Intelligence?



Learning is about seeking a predictive and/or executable understanding of natural/artificial subjects phenomena or activities from …

What is Machine Learning?

Machine learning seeks to develop theories and computer systems for

- Representing
- Classifying, clustering, recognizing
- Reasoning under uncertainty
- Predicting
- And reacting to
- …

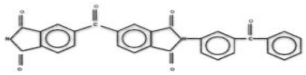
Complex, real world data, based on the system's own experience with data, and (hopefully) under a unified model or mathematical framework, that

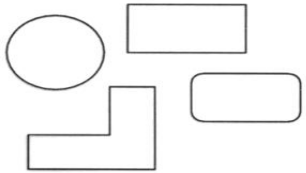
- Can be formally characterized and analyzed
- Can take into account human prior knowledge
- Can generalize and adapt across data and domains
- Can operate automatically and autonomously
- And can be interpreted and perceived by human

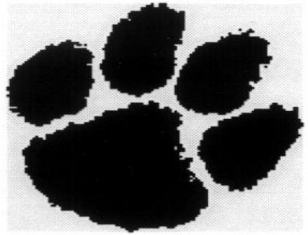
Pattern?

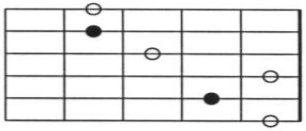
"A pattern is the opposite of a chaos; it is an entity vaguely defined, that could be given a name."

- Watanabe





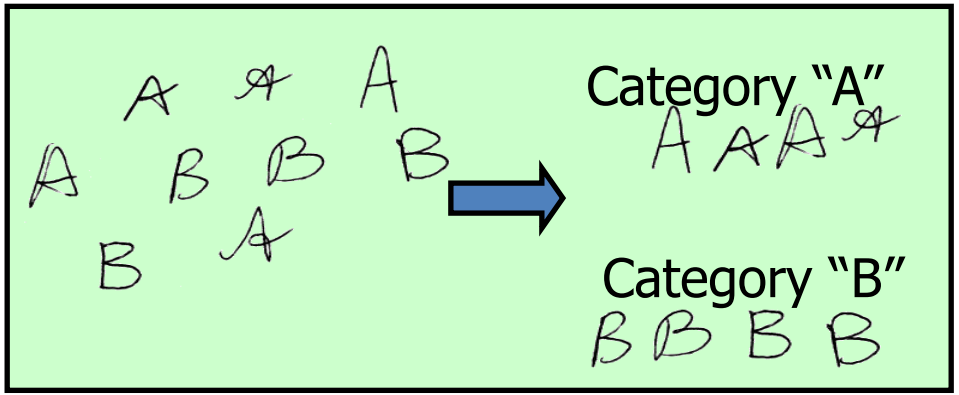




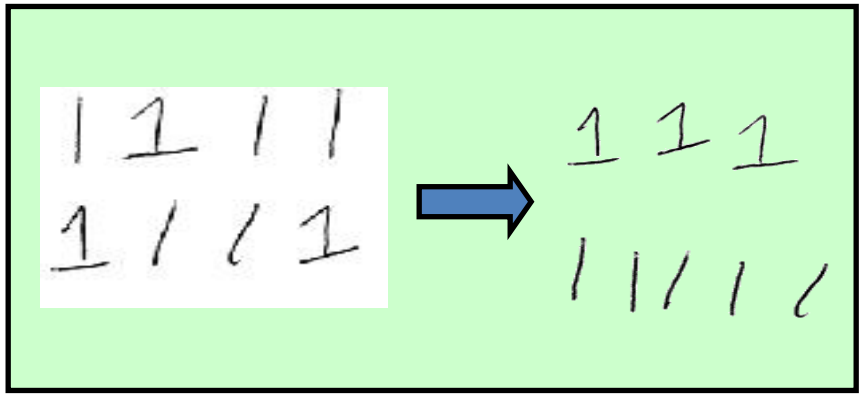
Recognition

Identification of a pattern as a member of a category we already know, or we are familiar with

- **Classification** (known categories)
- **Clustering** (learning categories)



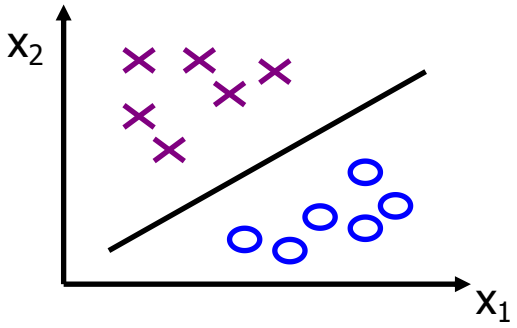
Classification

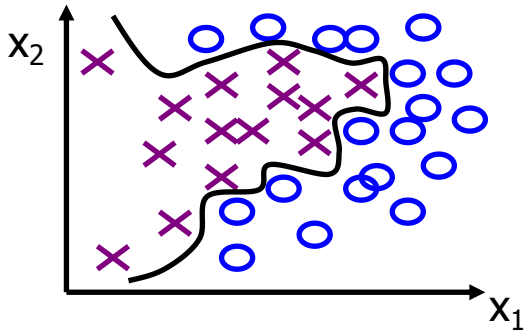


Clustering

Representation

- Each pattern is represented as **a point in *d*-dimensional feature space**
- Choice of features and their desired invariance properties are domain-specific





- Good representation implies (i) small intra-class variation, (ii) large inter-class separation and (iii) simple decision boundary

Pattern Class

- A collection of similar (not necessarily identical) objects
- A class is defined by class samples (paradigms, exemplars, prototypes, training/learning samples)
- Intra-class variability
- Inter-class similarity
- How do we define similarity?

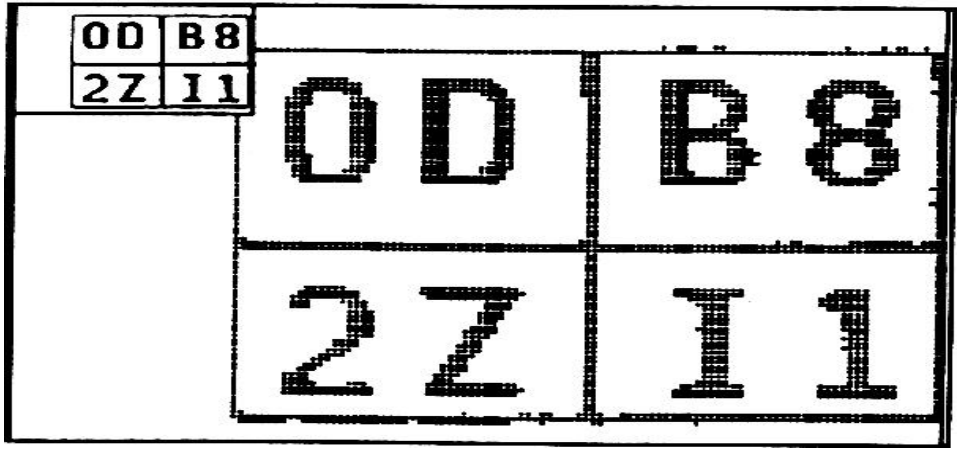
Intra-class Variability

The letter T in different typefaces

Same face under different expression, pose, illumination

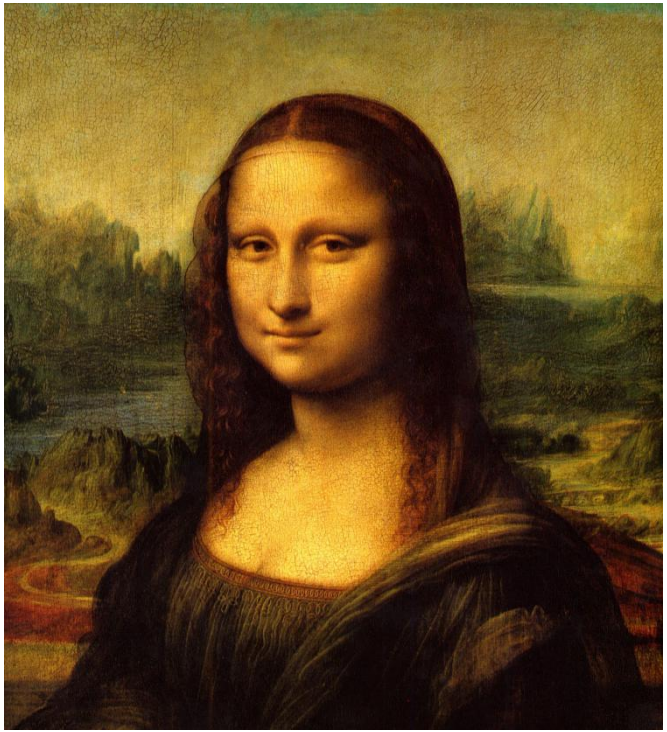
Inter-class Similarity

Identical twins



Characters that look similar

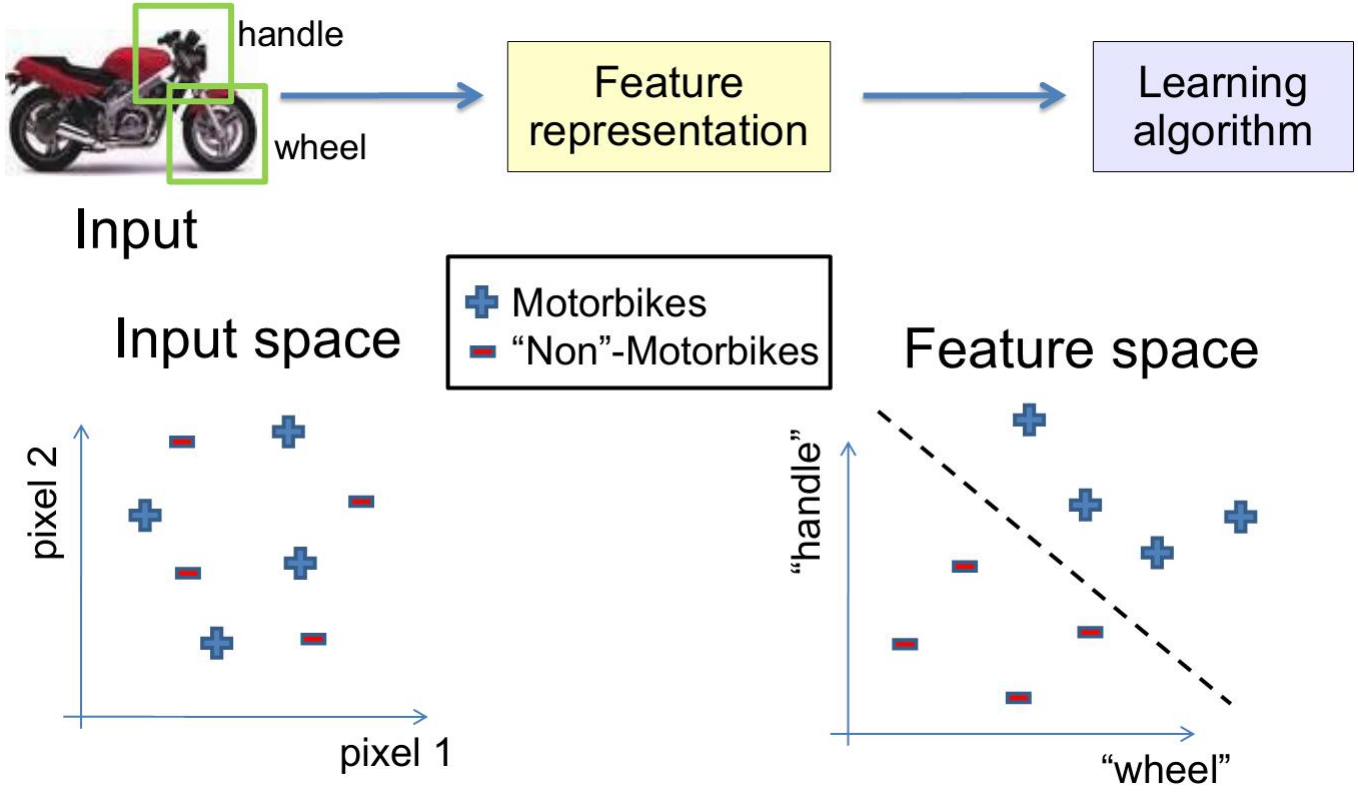
Inter-class or Intra-class?



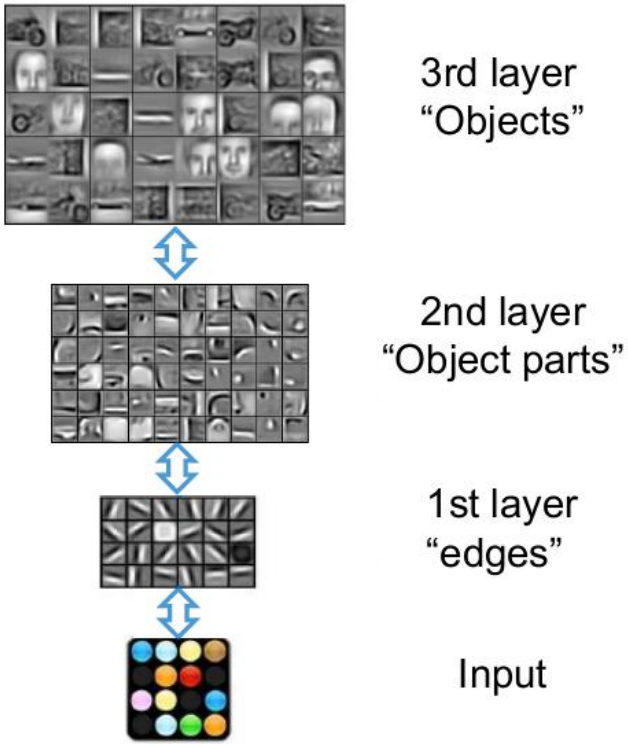
Good Representation

- Should have some invariant properties (e.g., rotation, translation, scale, …)
- Account for intra-class variations
- Ability to discriminate pattern classes of interest
- Robustness to noise, occlusion,..
- Lead to simple decision making strategies (e.g., linear decision boundary)
- Low measurement cost; real-time

Good Representation



Good Representation



- Represent objects from low-level to high-level structure
- Can share the low-level representation for multiple tasks

Deep Learning = Learning Hierarchical Representation

Traditional Pattern Recognition: Fixed/Handcrafted Feature Extractor

Feature Extractor → Trainable Classifier

Mainstream Modern Pattern Recognition: Unsupervised mid-level features

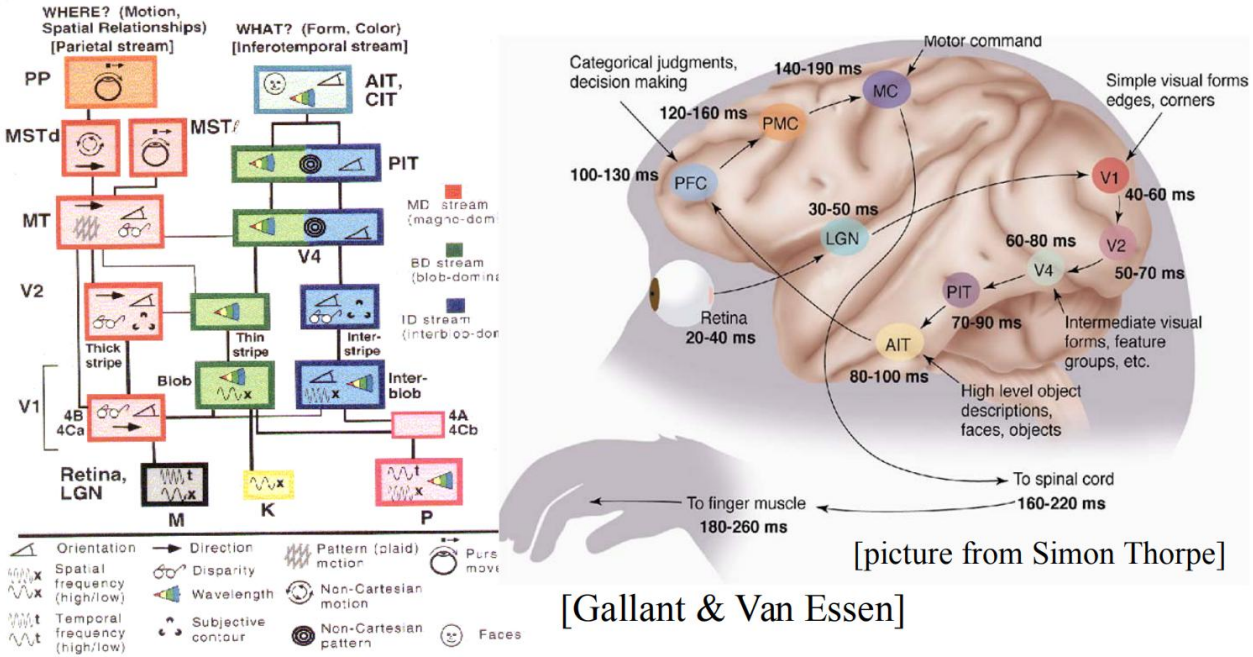
Feature Extractor → Mid-Level Features → Trainable Classifier

Deep Learning: Representations are hierarchical and trained

Low-Level Features → Mid-Level Features → High-Level Features → Trainable Classifier

The Mammalian Visual Cortex is Hierarchical

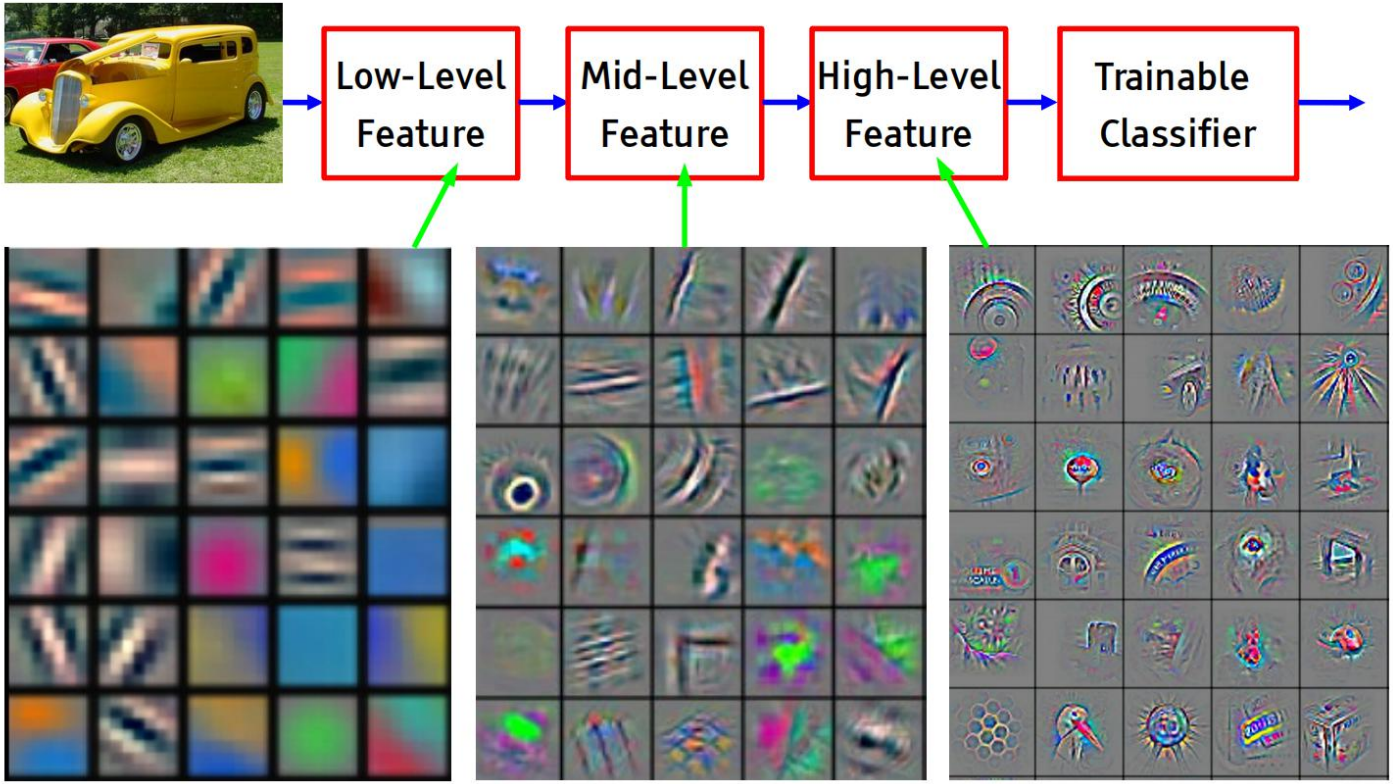
- The ventral (recognition) pathway in the visual cortex has multiple stages
- Retina - LGN - V1 - V2 - V4 - PIT - AIT ....
- Lots of intermediate representations



[Gallant & Van Essen]

Deep Learning = Learning Hierarchical Representation

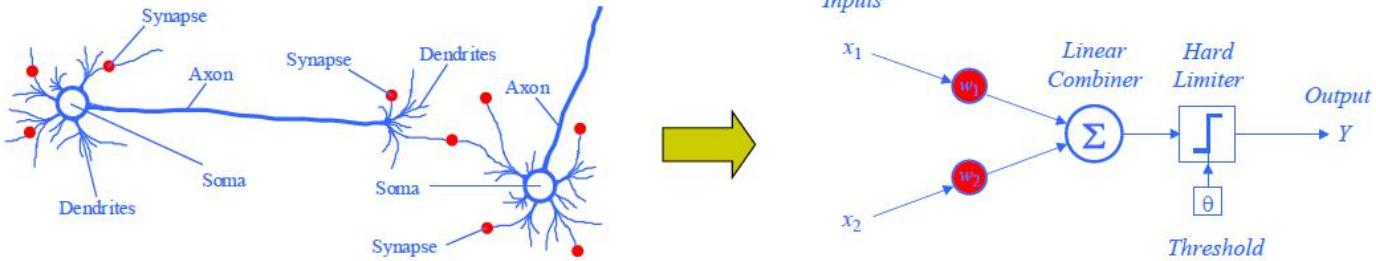
It's deep if it has more than one stage of non-linear feature transformation



Neural Networks and Deep Learning

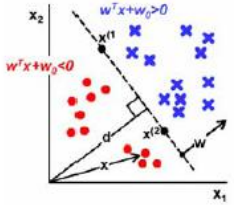
Perceptron and Neural Networks

- From biological neuron to artificial neuron (perceptron)

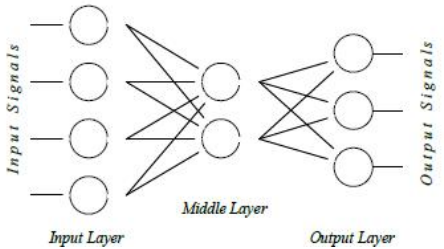


- Activation function

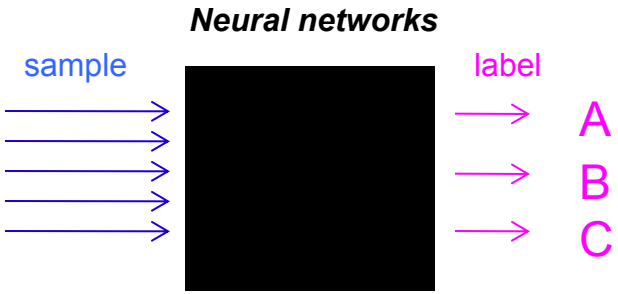
$$X = \sum_{i=1}^{n} x_i w_i \qquad y = \begin{cases} +1, & \text{if } X \geq \omega_0 \\ -1, & \text{if } X < \omega_0 \end{cases}$$

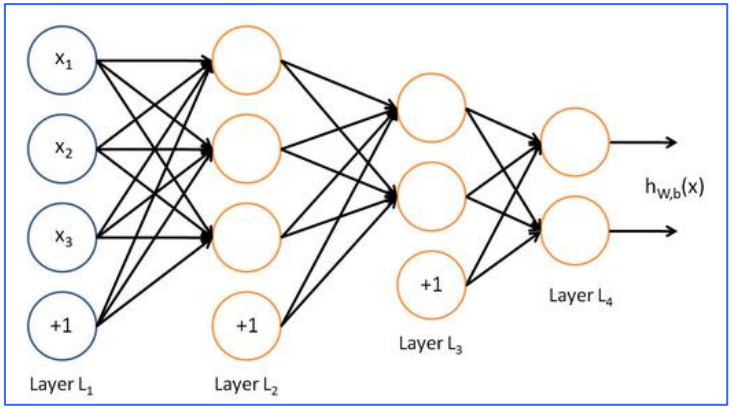


- Artificial neuron networks
  - supervised learning
  - gradient descent

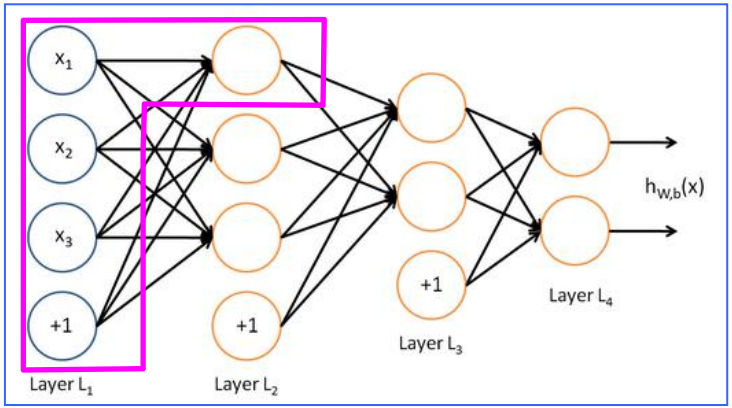


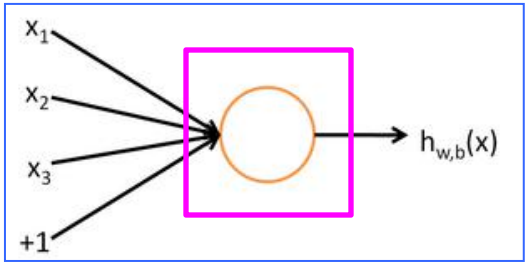
Neural Networks

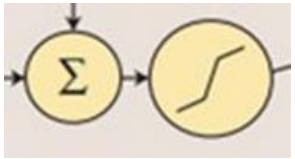




Neural Networks - Feedforward Networks





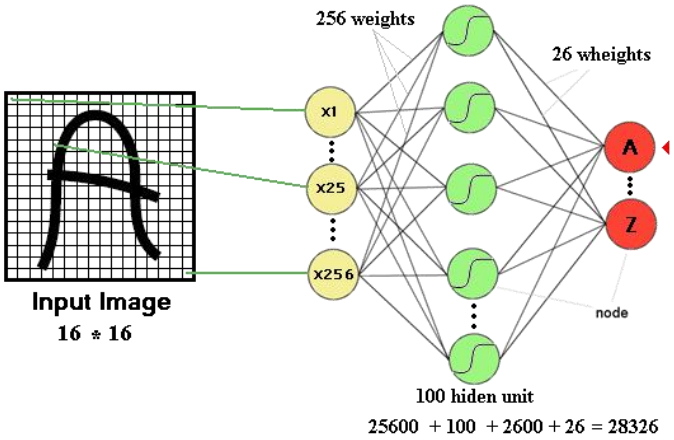


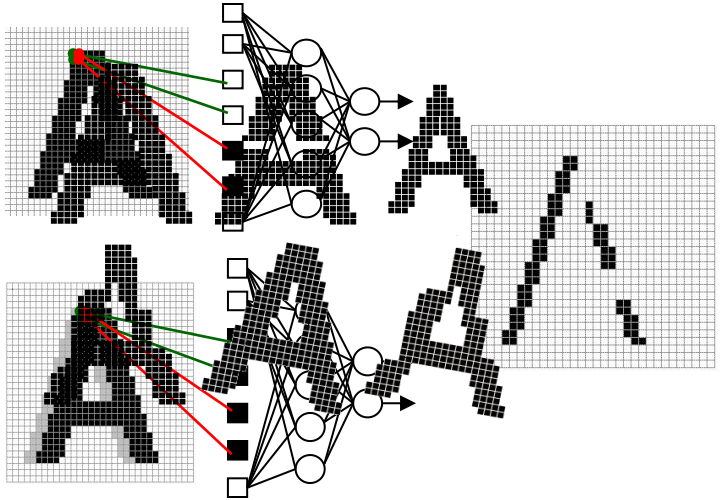
$$h_{W,b}(x) = f(W^T x) = f(\sum_{i=1}^{3} W_i x_i + b)$$

$$f(z) = \frac{1}{1 + \exp(-z)}$$

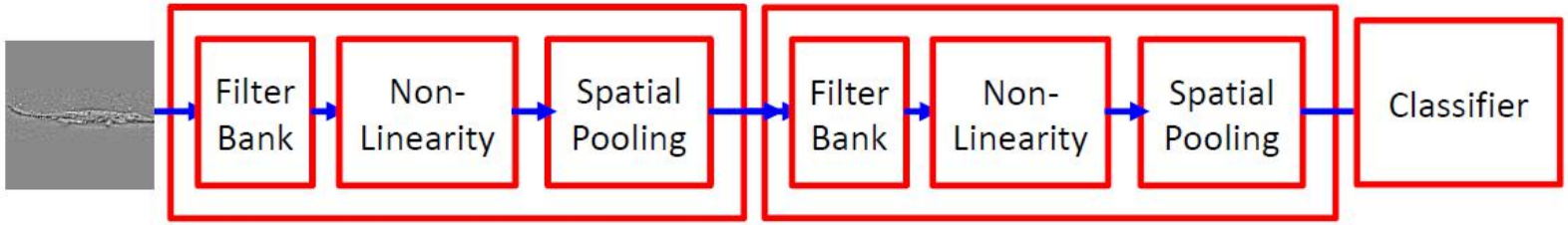
Neural Networks - Disadvantages

- The number of trainable parameters becomes extremely large
- Little or no invariance to shifting, scaling, and other forms of distortion



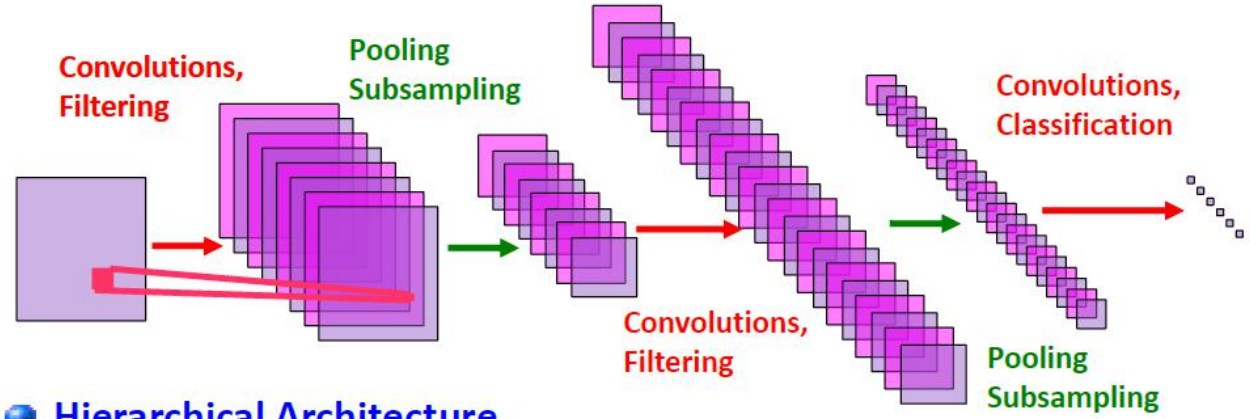


Hierarchical / Deep Architectures for Vision



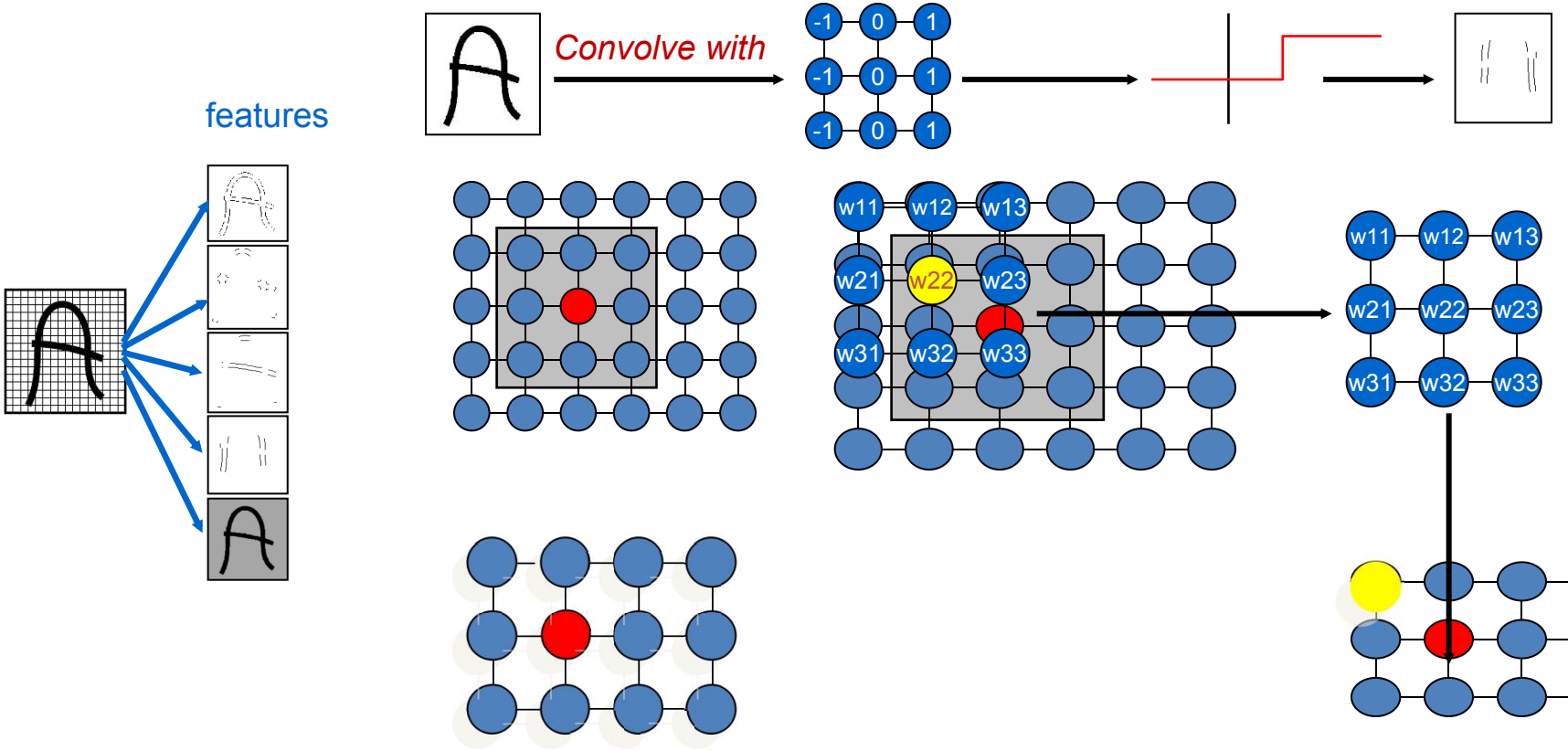
- Multiple Stages
- Each Stage is composed of
  - A bank of local filters (convolutions)
  - A non-linear layer (may include harsh non-linearities, such as rectification, contrast normalization, etc...).
  - A feature pooling layer
- Multiple stages can be stacked to produce high-level representations
  - Each stage makes the representation more global, and more invariant
- The systems can be trained with a combination of unsupervised and supervised methods

Convolutional Network: Multi-stage Trainable Architecture

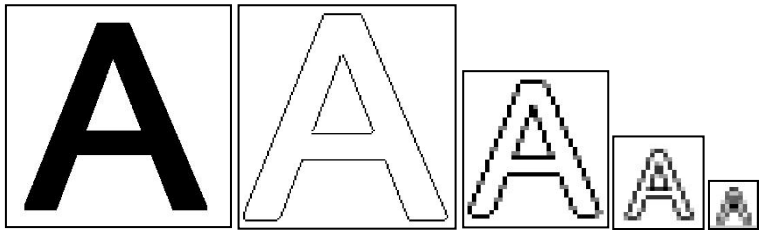


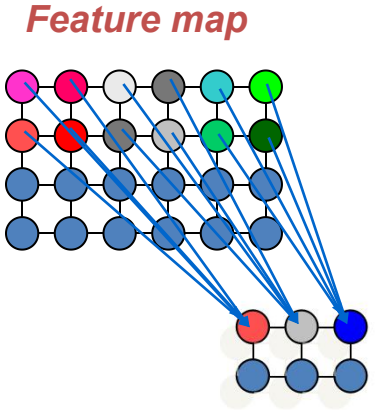
- **Hierarchical Architecture**
  - Representations are more global, more invariant, and more abstract as we go up the layers
- **Alternated Layers of Filtering and Spatial Pooling**
  - Filtering detects conjunctions of features
  - Pooling computes local disjunctions of features
- **Fully Trainable**
  - All the layers are trainable

Convolutional layer or Feature Extraction Layer



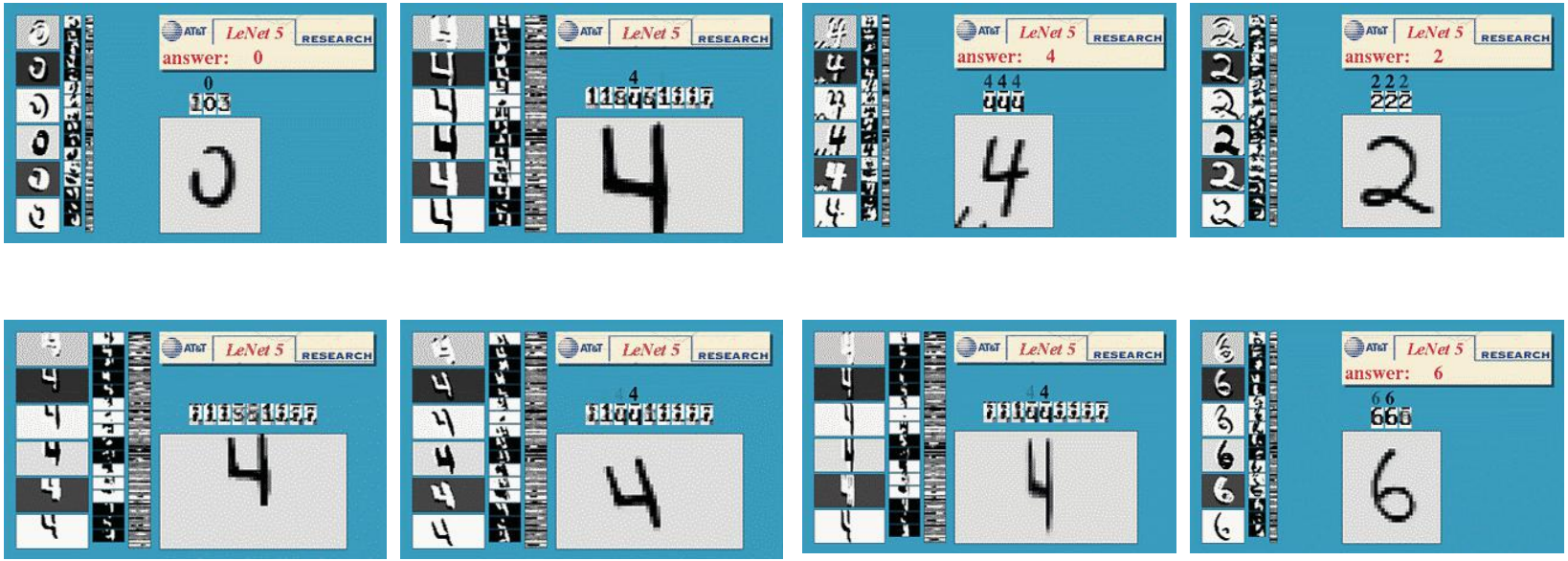
Subsampling Layer





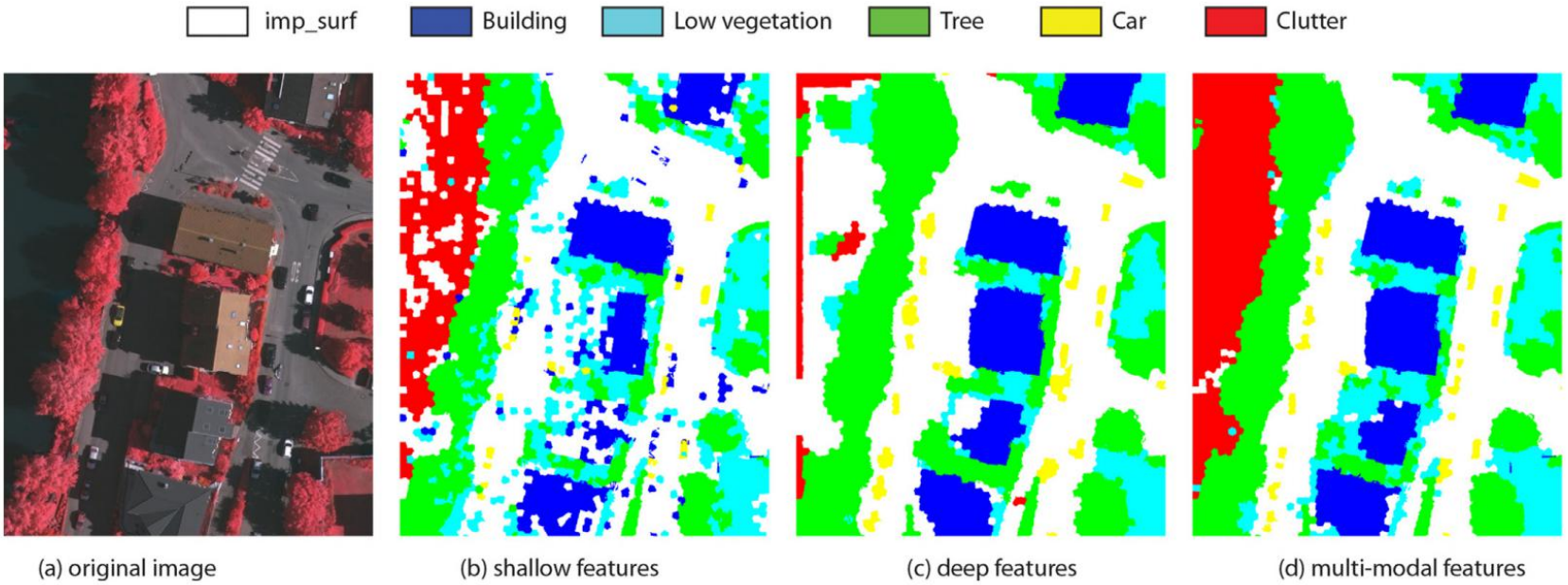
- By reducing the spatial resolution of the feature map, reduce the effect of noises and shift or distortion.
- The weight sharing is also applied in subsampling layers

Convolutional Networks Architecture for Hand-Writing Recognition



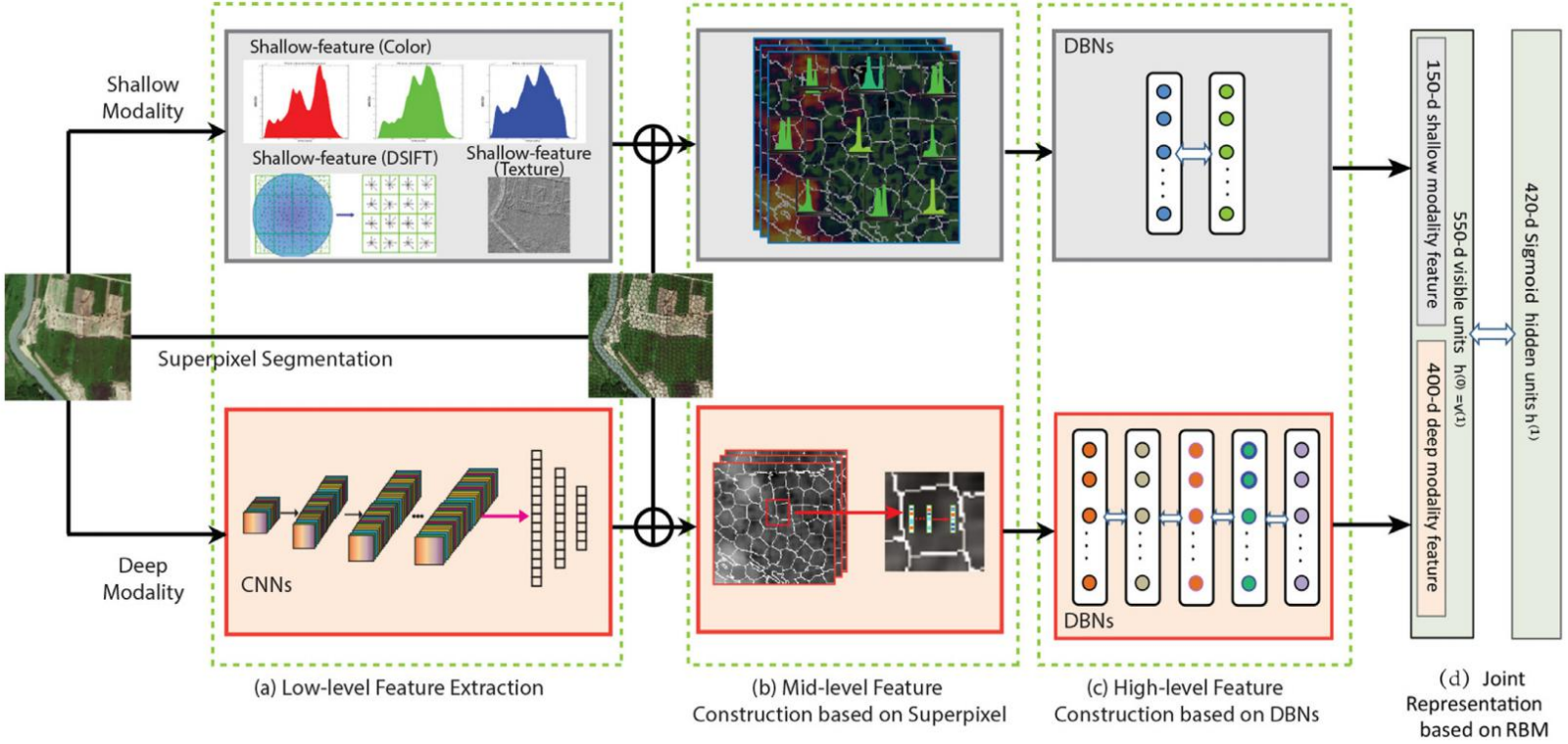
Applications

Application (1) Image Annotation



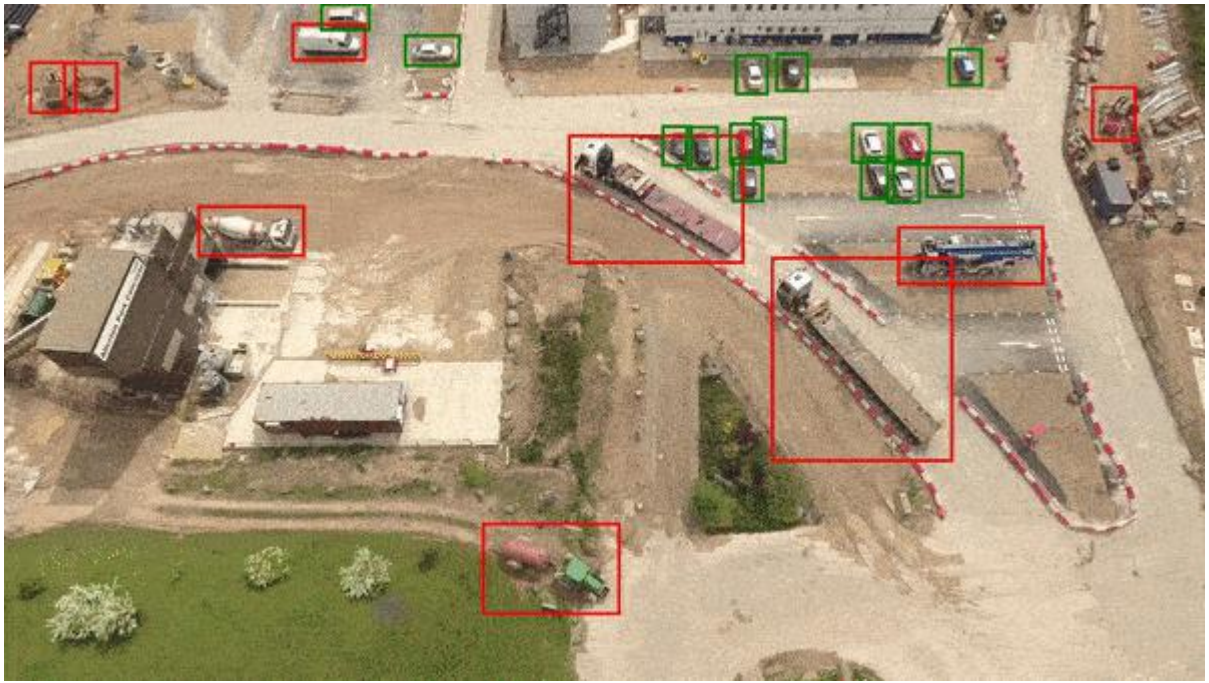
Ke Li, et al. Multi-modal feature fusion for geographic image annotation

Application (1) Image Annotation



Ke Li, et al. Multi-modal feature fusion for geographic image annotation

Application (2) Object Detection



Joseph Redmon, et al. YOLOv3: An Incremental Improvement

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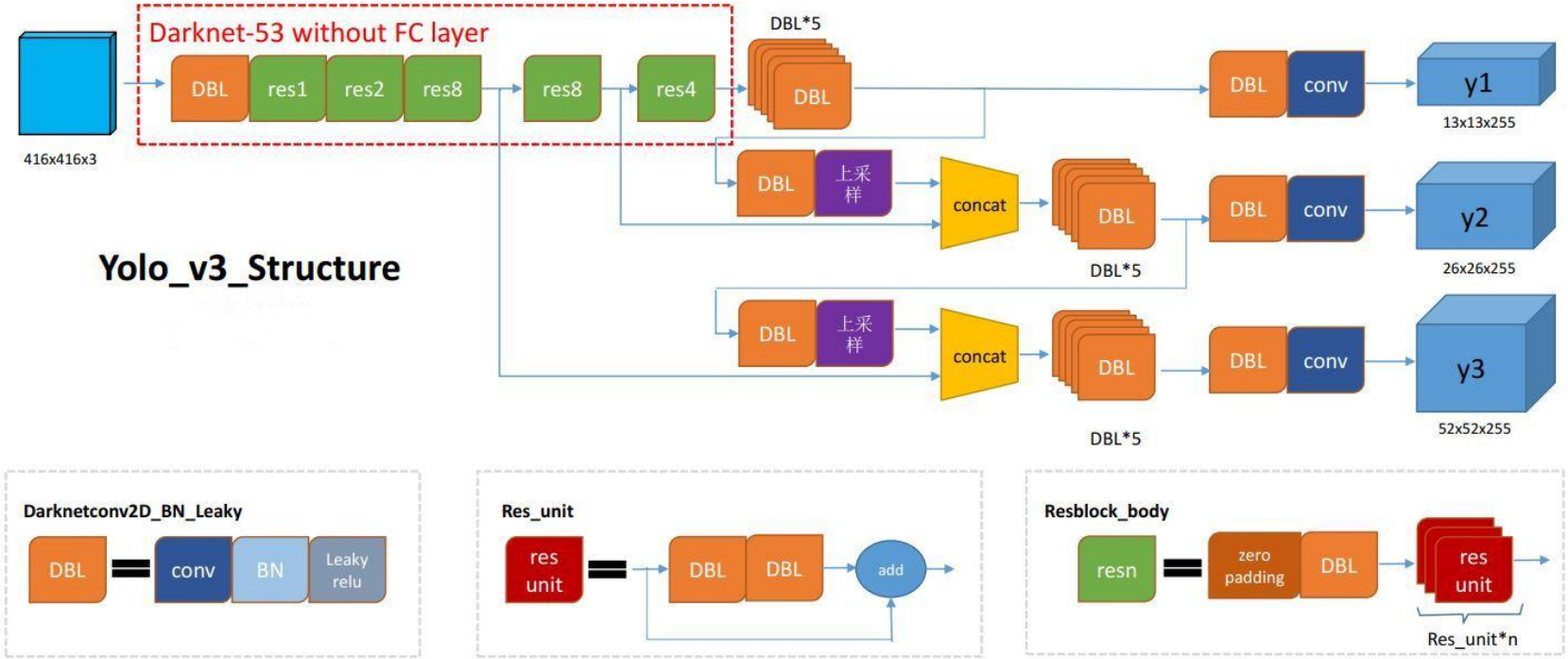


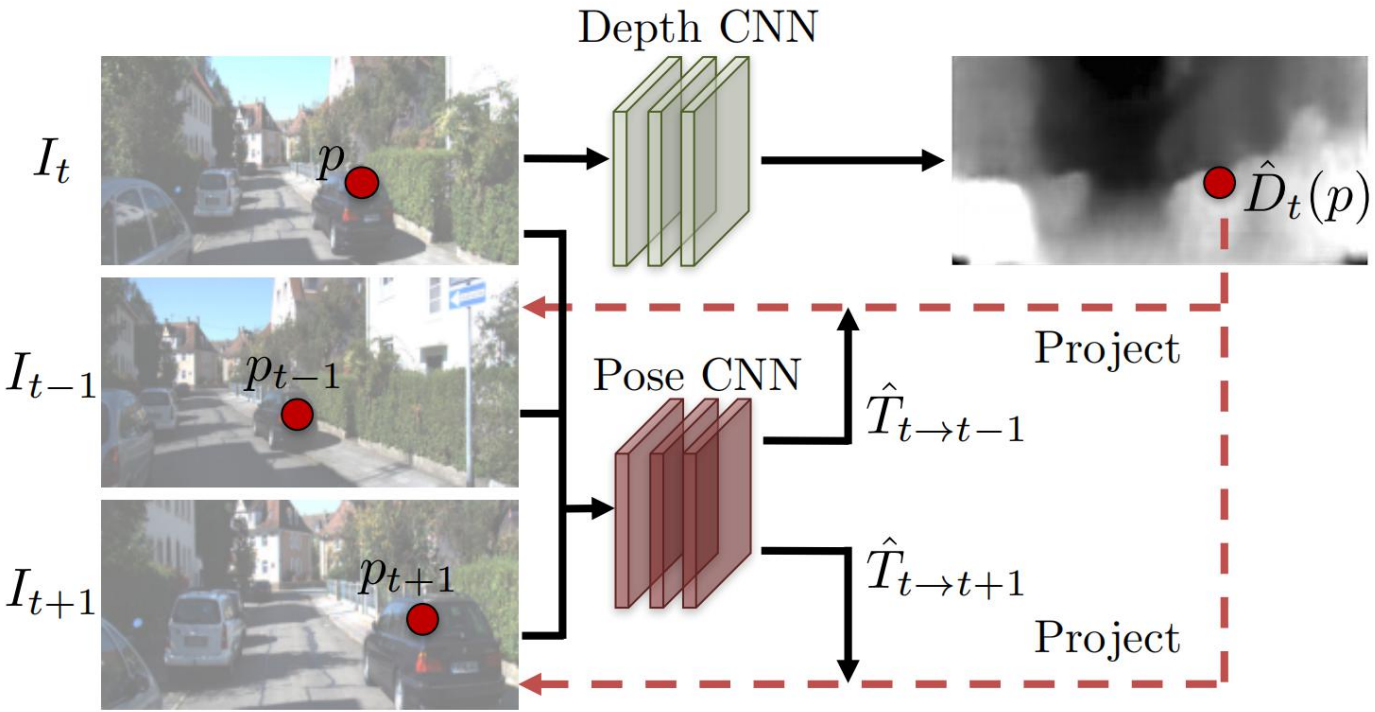
Joseph Redmon, et al. YOLOv3: An Incremental Improvement

Application (3) Deep Learning based SLAM

Estimate position and depth image simultaneously

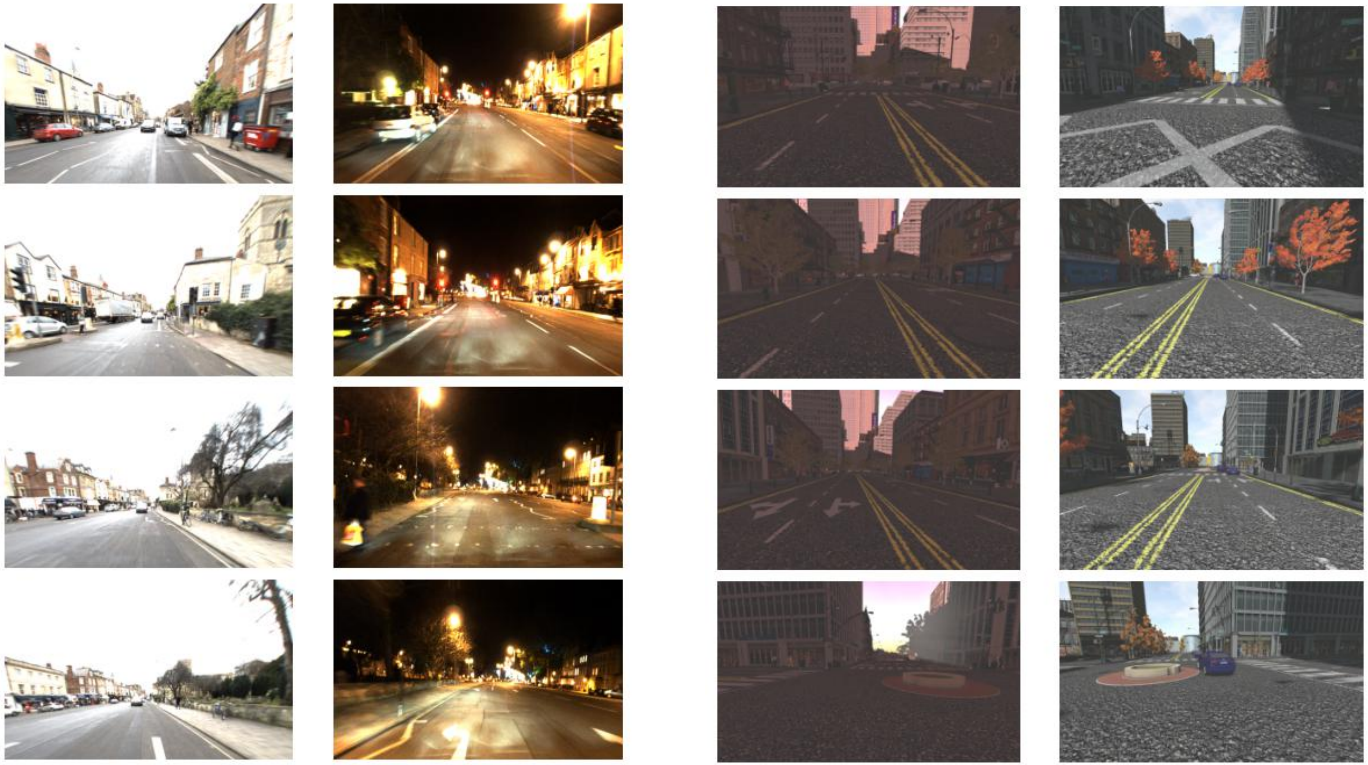
Tinghui Zhou, et al., Unsupervised Learning of Depth and Ego-Motion from Video

Application (3) Deep Learning based SLAM



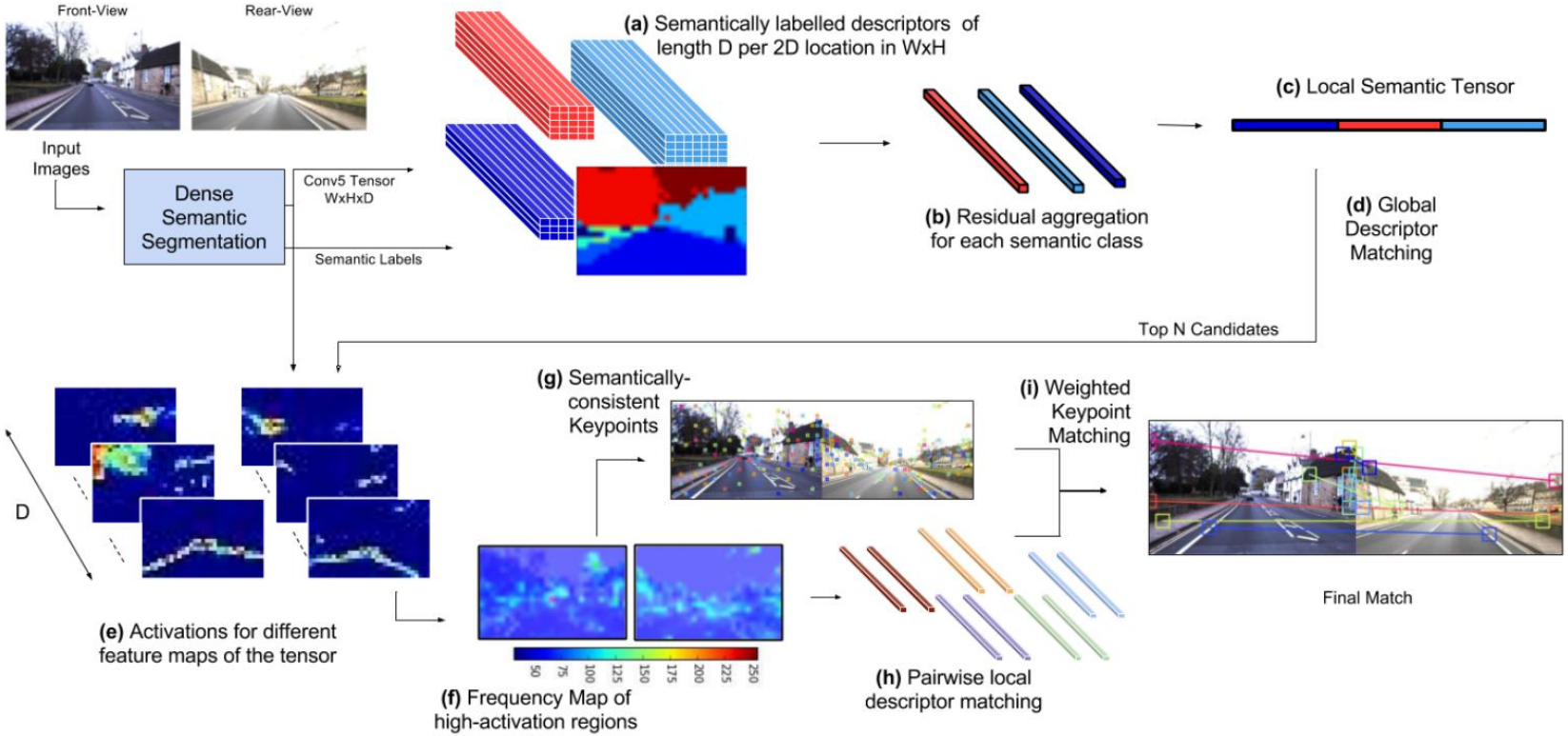
Tinghui Zhou, et al., Unsupervised Learning of Depth and Ego-Motion from Video

Application (4) Place Recognition



Sourav Garg, et al., LoST? Appearance-Invariant Place Recognition for Opposite Viewpoints using Visual Semantics

Application (4) Place Recognition



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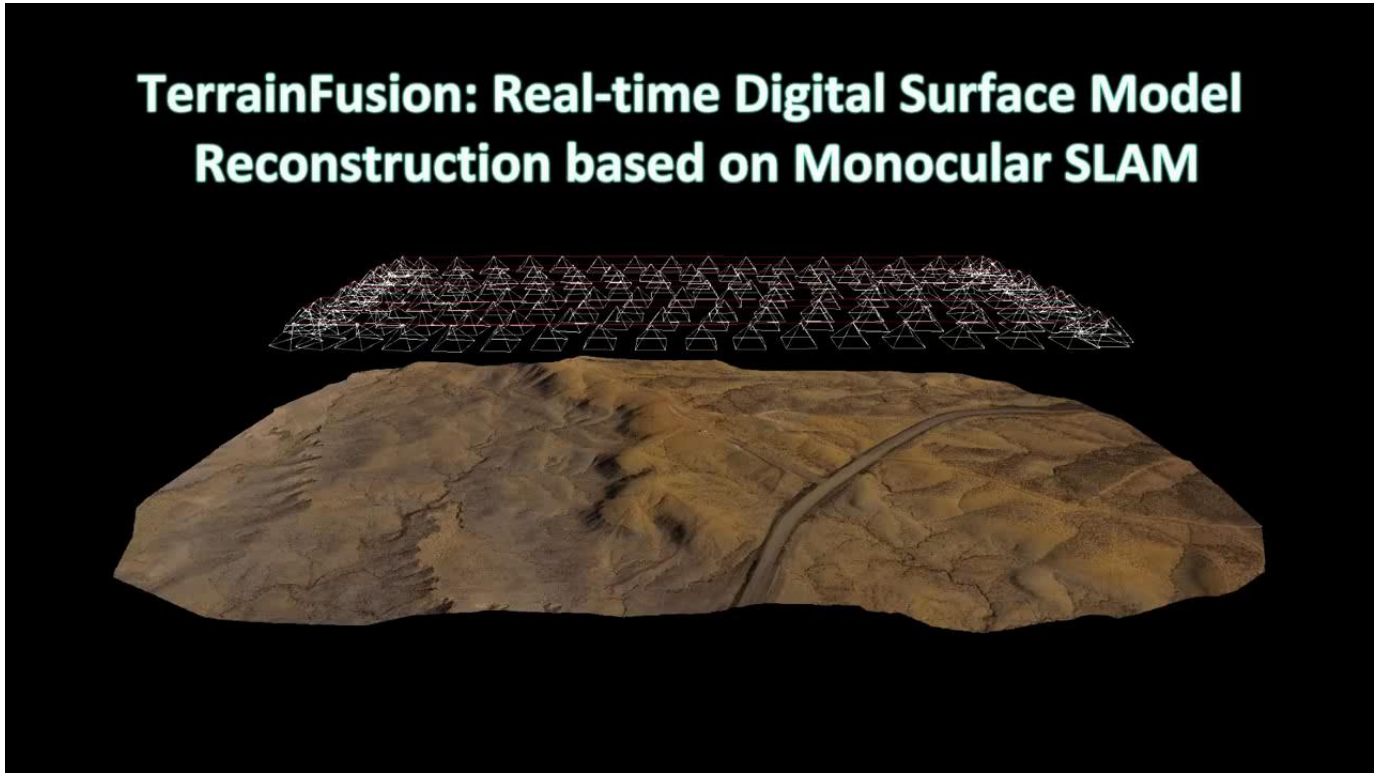
Application (5) Realtime 3D Map



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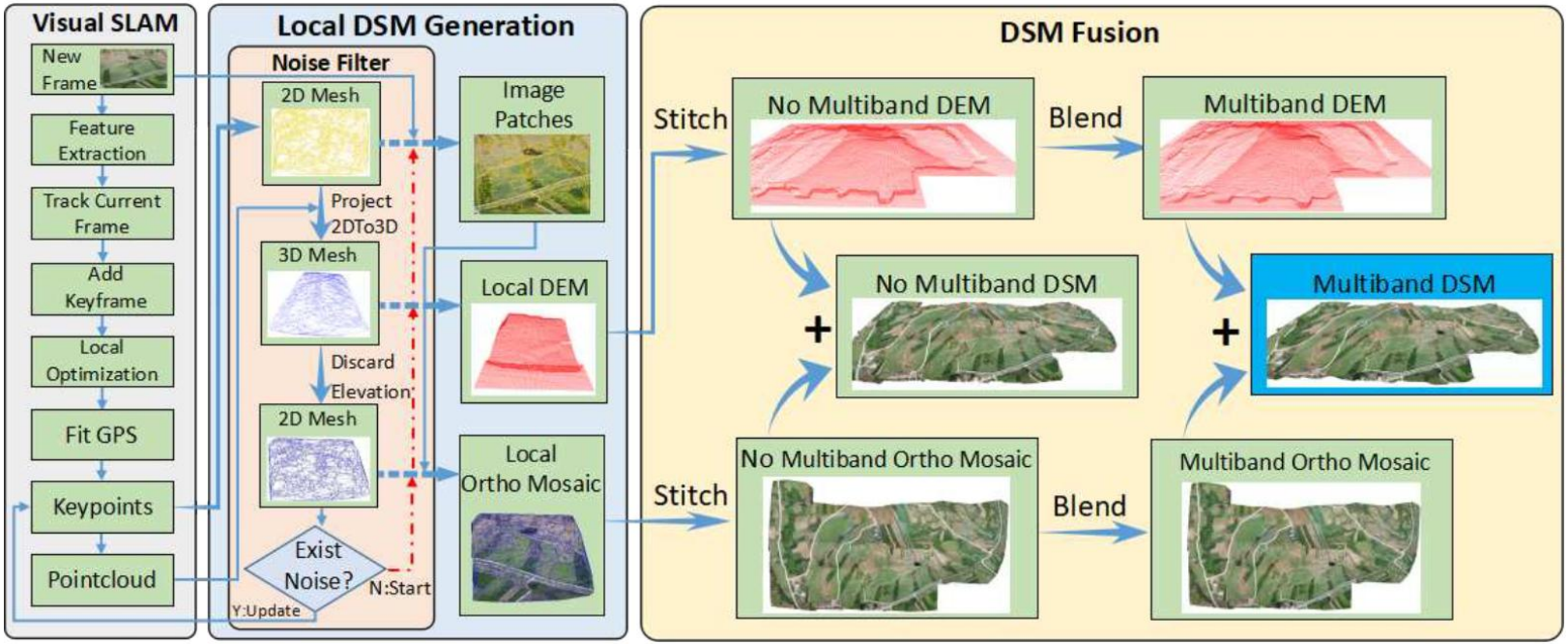
Application (5) Realtime 3D Map



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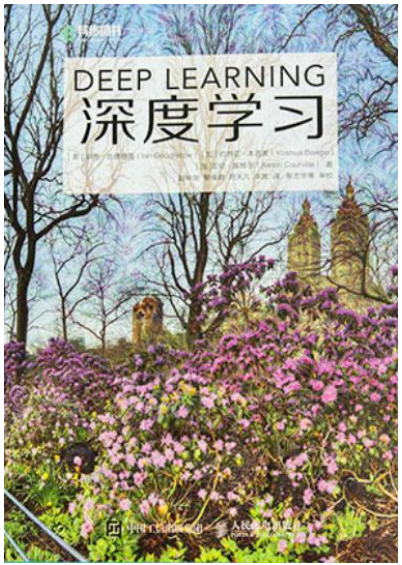
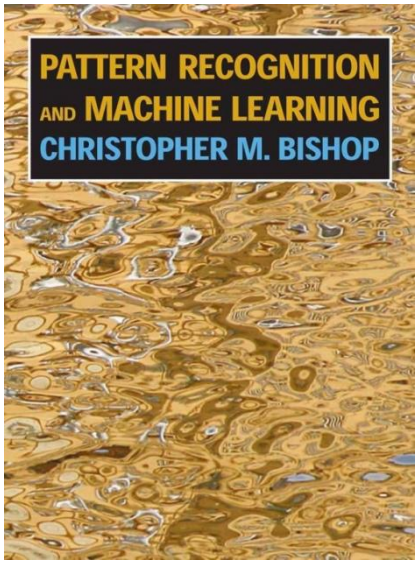
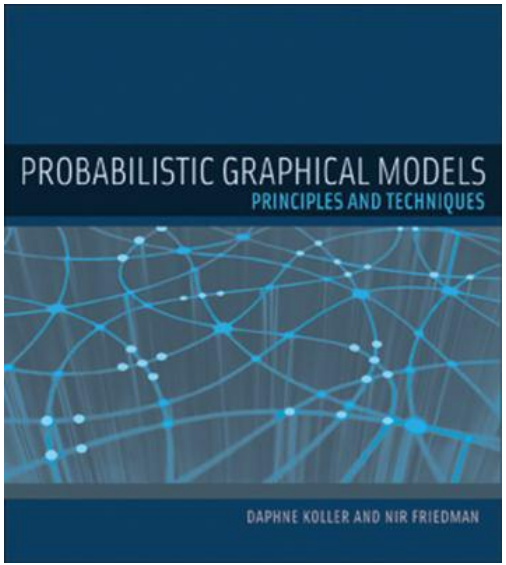
Summary

- General-purpose intelligent system is a very difficult problem
- Successful systems available in well-constrained domains
- All components are coupled
- No single approach has been found to be optimal for all problems
- Use of object models, constraints and context is necessary for identifying complex patterns
- Careful sensor design and feature extraction often lead to simple classifiers

Books


DEEP LEARNING
深度学习


PATTERN RECOGNITION
AND MACHINE LEARNING
CHRISTOPHER M. BISHOP


PROBABILISTIC GRAPHICAL MODELS
PRINCIPLES AND TECHNIQUES
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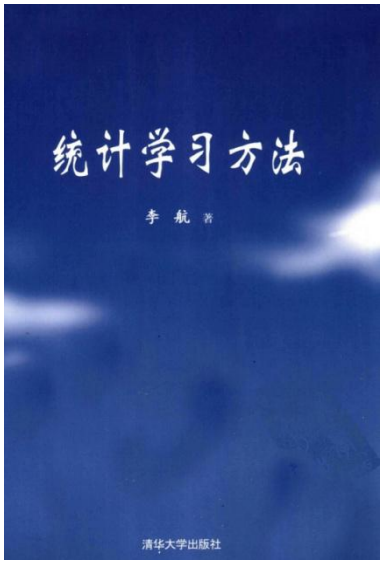
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Homework: https://gitee.com/pi-lab/machinelearning_homew

Notebook

Homework

THANK YOU