Types of Learning

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Introduction

This article is the study notes of the course: The foundation of Machine Learning. In today's speech, Professor Lin introduces different types of machine learning problems. In general, we can classify different machine learning problems from the perspective of **the output space Y, the data label, the protocol and the input space.**

1 Learning with different output space Y

1.1 Structured Learning: Sequence Tagging Problem

$$I \quad love \quad ML$$
$$pronoun \quad verb \quad noun$$

- multiclass classification: word $\Rightarrow$ word class
- structured learning: sentence $\Rightarrow$ (class of each word)
- $Y = \{PVN, PVP, NVN, PV, ...\}$, not including $VVVVV$
- huge muticlass classification problem (structure = hyperclass) without 'explicit' class definition

1.2 Mini Summary

- binary classification:$Y = \{-1, +1\}$
- multiclass classification: $Y = \{1, 2, ..., K\}$
- regression: $Y = R$
- structured learning: $Y =$ structures
- and a lot more

2 Learning with different Data Label

2.1 Supervised learning

Every x_n comes with corresponding y_n

2.2 Unsupervised Learning

'Learning without y_n'

- clustering: $\{x_n\} \Rightarrow cluster(x)$
  ($\approx$ 'unsupervised multiclass classification')
  i.e. articles $\Rightarrow$ topics
- density estimation : $\{x_n\} \Rightarrow density(x)$
  ($\approx$ 'unsupervised bounded regression')
  i.e. traffic reports with location $\Rightarrow$ dangerous areas
- outlier detection $\{x_n\} \Rightarrow unusual(x)$
  ($\approx$ extreme 'unsupervised binary classification')
  i.e. Internet logs $\Rightarrow$ intrusion alert
- and a lot more

2.3 Semi-supervised learning

Leverage unlabeled data to avoid 'expensive' labeling.

- face images with a few labeled $\Rightarrow$ face identifier (Face book)
- medicine data with a few labeled $\Rightarrow$ medicine effect predictor

2.4 Reinforcement Learning

Learn with 'partial/implicit information' (often sequentially)

Other Reinforcement Learning Problems Using ($x, \sim y, goodness$)

- (customer, ad choice, ad click earning) $\Rightarrow$ ad system
- (cards, strategy, winning amount) $\Rightarrow$ black jack agent

2.5 Mini Summary

- supervised: all y_n
- unsupervised: no y_n
- semi-supervised: some y_n
- reinforcement: implicit y_n by goodness $\sim y_n$
- and more

3 Learning with Different Protocol

3.1 Batch learning

Learn from all known data.

3.2 Online: Spam Filter that 'Improves'

Hypothesis "improves" through receiving data instances sequentially.

- batch spam filter:
  learning with known (email, spam?) pairs, and predict with fixed g
- online spam filter, which sequentially:
  - observe an email x_t
  - predict spam status with current $g_t(x_t)$
  - receive 'desired label' y_t from user, and then update g_t with (x_t, y_t)

3.2.1 Connection to What We Have Learned

- PLA can be easily adapted to online Protocol
- Reforcement learning is often done online

3.3 Learning Philosophy

- batch: 'duck feeding'
- online: 'passive sequential'
- active: strategically-observed data
- and more

active: improve hypothesis with fewer labels(hopefully) by asking questions strategically.

4 Learning with Different Input Space

4.1 Concrete features

Each dimension of $X \subset R^d$ represents 'sophisticated physical meaning'.

4.2 Raw features

- image pixels, speech signal, etc

Often need human or machines to convert to concrete ones.

4.3 Abstract features

Need 'feature conversion/extraction/construction'

- given previous (userid,itemid,rating) tuples, predict the rating that some userid would give to itemid?
- a regression problem with $Y \subset R$ as rating and $X \subset N \times N$ as (userid, itemid)
- 'no physical meaning'; thus even more difficult for ML

Other Problems with Abstract Features

- student ID in online tutoring system
- advertisement ID in online ad system

4.4 Mini Summary

- concrete: sophisticated (and related) physical meaning
- raw: simple physical meaning
- abstract: no (or little) phyical meaning
- and more