Perspectives on Abductive Learning

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March 1, 2020

Abstract

Abductive Learning (ABL) is a hybrid model with a machine learning stage and logical abduction stage. ABL is convinced to be method to bridge perception and reasoning. In this paper, I reviewed the essential of ABL and share my perspectives on future artificial intelligence.

1 Abduction and Induction

Generally abduction is defined as "inference to the best explanation" according to ovserved phenomena, where *best* refers to the generated hypothesis subjected to some optimal indicators.
Abduction can be intuitively explained as finding a specific cause from result and induction can be explained as finding a general result from cause. The main distinction between abduction and induction is that the former gives inference to extention knowledge while the latter gives inference to intention knowledge.

2 Abductive Learning

The goal of Abductive Learning (ABL) is predicting a hypothesis model which satisfies the consistency between perception result $P \in \{p_1, \ldots, p_i\}$ and predefined domain knowledge base B. Let C be the target concept and Δ_C be a first-order clauses based knowledge model. The target model $p \cup \Delta_C$ is a perception model with logical modification. Intuitively, ABL learns both patterns and essence underneath the patterns in contrary to perceptual machine learning models.

2.1 Machine Learning: Peception

The first stage of ABL is learning an $f : X \to Y$, where f is a function to be learned from sample space $X \in \{x_1, \ldots, x_i\}$ to label space $Y \in \{y_1, \ldots, y_i\}$. The predicted labels of the input data are denoted as pseudo-lables $p(x_i)$ in contrary to ground-labels in conventional machine learning tasks (e.g. classification).

2.2 Logical Abduction: Reasoning

We denote an abductive logic program as a triplet (B, A, IC) where B is background knowledge, A is a set of abductive predicates and IC is the integrity constraints. Let O be observation facts and $\models$ be logical entailment. The output Δ satisfies

- $B \cup \Delta \models O$
- $B \cup \Delta \models IC$
- $B \cup \Delta$ *is consistent*

To train ABL, we maximizes the consistency between training examples denoted by $D = \{x_i, y_i\}$ and domain knowledge.

$$\max_{H=p \cup \Delta C} Consistency(H \cup D; B) \tag{1}$$

2.3 Minimal Modification

The pseudo-labels generated in machine learning stage may consist of incorrect labels. We employ a heuristic function δ which is subjected to

$$|\delta[p^t(X)]| \leq M \tag{2}$$

where M is small number denoting searching step and t denotes $t-th$ epoch of ABL training. This means the revision of pseudo-lables is not far away from their original location. Then we can abduce the candidate pseudo-labels by

$$H_\delta = B \cup p^t(X) - \delta[p^t(X)] \cup \Delta_{\delta[p^t(X)]} \cup \Delta_C^t \models Y \tag{3}$$

2.4 Retrain the Perception Model

After revising the pseudo-labels by minimal modification, we obtain data with abductive-labels $r(x_i)$. The we train the machine learnin model under the supervision of abductive data.

$$p^{t+1} = \arg\min_p \sum_{i=1}^{m} \mathcal{L}(p(x_i); r(x_i)) \tag{4}$$

where $\mathcal{L}$ denotes the loss function of the perception model.

3 Future Artificial Intelligence

I've been thinking about future artificial intelligence for months and I know that conventional machine learning model is insufficient for General, Robust artificial intelligence. Though obtaining dramatical performance on tasks like Computer Vision and Natural Language Processing, deep network based models remain unreliable, data-consuming and energy-consuming. Intuitively, they only learn "what to output for a specific pattern of input", but they "don't know why they do so". Hence, researchers design many ways to make training data cover all extreme cases, such as larger scale datasets. The factors above limits the industrial developing of AI due to higher and higher training cost.

In my view, the ABL framework is a reciprocative model with a classifier supervised by knowledge base and a search-space-pruned logical abduction programmer. ABL may obtain much more reliable results with much less cost because it is much more closer to the essence of cognition. In fact, human learns by trail-and-error instead of minimizing a derivative function.

Can we power the perceptive models with cognitive models? Take visual object detection for instance, can we improve a detector with mechanisms to "let it know its result is not consistent with background knowledge", i.e. let it be aware of its failure and make minimum calibration during testing stage? We still have a long way to go.