Classification of Intelligence by Meta-Models

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We propose a novel classification of artificial intelligence based on computational problems vs. learning problems. We show how learning problems are solved like computational problems and iterate the process to arrive at an infinite sequence of meta-learning processes. In order to achieve general learning, we break the infinite sequence by means of a self-referential meta-model, which poses additional constraints for general intelligence in formal systems.

Introduction

Definition of **Intelligence** in this work: The capability to solve problems.

Definition of **General Learning** in this work: The capability of acquiring any model in the search space.

Problem: General learning remains elusive in Artificial Intelligence. More insight is needed.

Objective: Provide new insights into general learning that show why does it remain elusive.

Computational Problems

➡ Input (I) and method (f) are known. $I \xrightarrow{f} ?$

➡ Output (O) is unknown. $f(I) = ?$

Examples
- ✓ Algorithmic evaluation
- ✓ Turing machines
- ✓ Trained neural networks
- ✓ Functions whose output is data

Learning Problems

➡ Input (I) and output (O) are known. $I \xrightarrow{?} O$

➡ Method (f) is unknown. $?(I) = O$

Examples
- ✓ Training algorithms of neural networks
- ✓ Reinforcement learning
- ✓ Genetic programming
- ✓ Functions whose output is another function

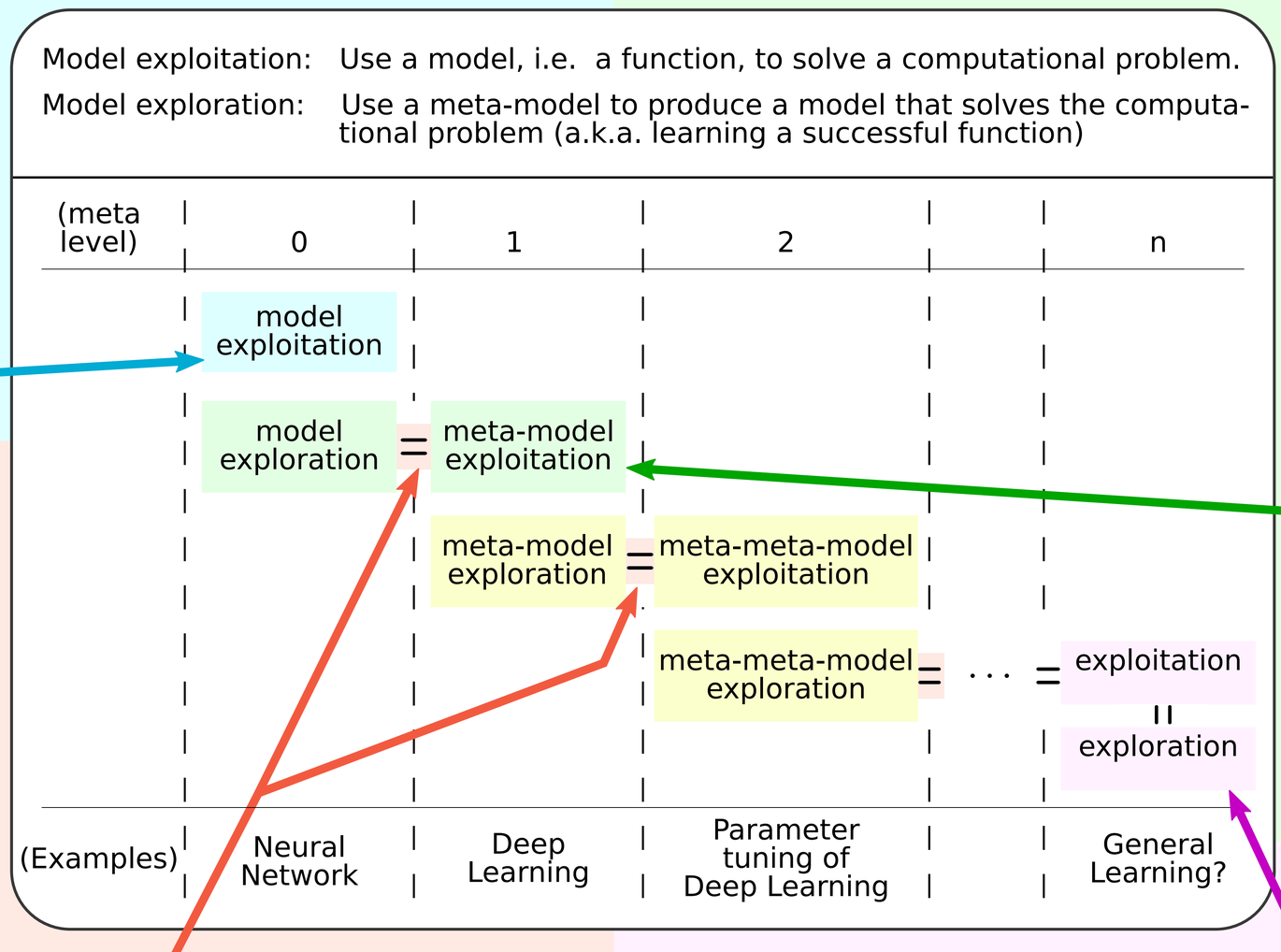
Resolution of computational problems:

➡ Execute f in a CPU with I as input data. The result is O.

➡ Analogous to exploit-ation of the implicit model in f.

Model exploitation: Use a model, i.e. a function, to solve a computational problem.

Model exploration: Use a meta-model to produce a model that solves the computational problem (a.k.a. learning a successful function)



Resolution of learning problems:

➡ Execute a meta-model (g) that maps I and O to the appropriate function.

➡ Analogous to exploration of model space f_k.

Recursive meta-learning

➡ Learning problems

$$I' := I \xrightarrow{?} O$$

are meta-computational problems:

$$I' \xrightarrow{g} ?$$

where g is a function with an implicit meta-model:

$$g(I') = O' ; \quad O' := I \xrightarrow{f} O$$

➡ When g cannot provide an appropriate f in O', then we have a meta-learning problem:

$$I' \xrightarrow{?} O'$$

➡ Applying induction yields a chain of meta-learning problems.

➡ The last element in the chain sets the limits to learning.

➡ Infinite chains are not realizable.

Our proposal

➡ We propose a self-referential meta-model as an alternative to the infinite sequence of meta-learning processes in order to achieve general learning.

➡ This meta-model (a.k.a. meta-function) modifies itself, so that the computational problem is the same as the learning problem.

➡ However, formal systems cannot achieve general meta-learning this way because of issues related to incompleteness, inconsistency and the P-NP problem.

Conclusions

✓ Methods in Artificial Intelligence can be classified by their meta-learning capabilities, rather than their function or methods used.

✓ Computation devices based on formal systems cannot achieve general learning, as defined above.

Future works

✓ Explore the possibility of self-referential general learning systems that are not formal, i.e. stochastic processes.

✓ Reinforcement learning and genetic programming are good candidates.

References

- Gödel, K. (1931). Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme I. Monatshefte Für Mathematik Und Physik, 38(1), 173–198.
- Naik, D. K., & Mammone, R. J. (1992). Meta-neural networks that learn by learning. In International Joint Conference on Neural Networks, Vol. 1, 437–442.
- Schmidhuber, J. (2005). Gödel Machines: Self-Referential Universal Problem Solvers Making Provably Optimal Self-Improvements. In Artificial General Intelligence, 5.
- Turing, A. M. (1939). Systems of Logic Based on Ordinals. In Proceedings of the London Mathematical Society, 161–228.
- Unruh, A., & Rosenbloom, P. S. (1989). Abstraction in Problem Solving and Learning. In Proceedings of the 11th International Joint Conference on Artificial Intelligence, 681–687.