“Easy” presentation

The logic route to strong AI

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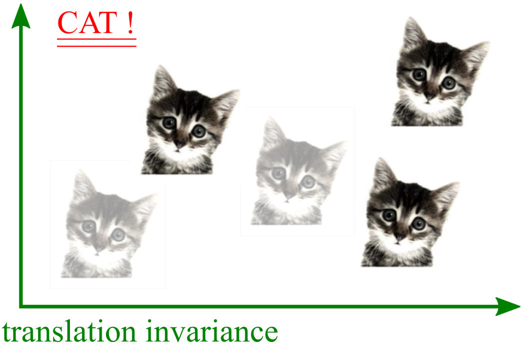
CNN 在机器视觉中的成功

- 在几何学上，视觉 具有 **平移 不变性**：



(1)

- Convolution 是一种具有平移不变性的运算：

$$(T_x \circ f) * g = T_x \circ (f * g) \tag{2}$$

- Yann LeCun 等人 利用 CNN 的 **对称性** 加快了学习速度，成功地解决了机器视觉 的问题

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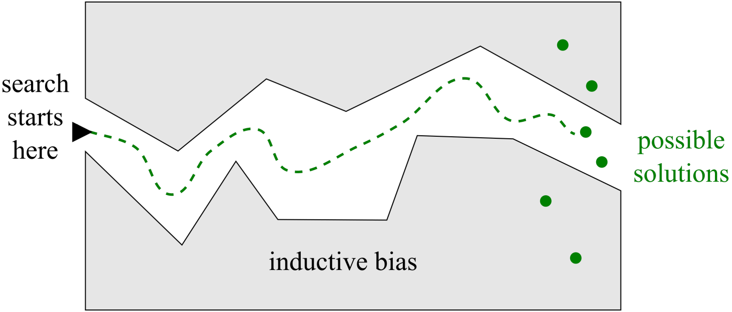
Symmetry and inductive bias

- 在数学上，**对称性** 经常能简化计算，所以数学家 特别喜欢 对称
- 在机器学习中，经常要引入 归纳偏好 (inductive bias)，缩小 **搜寻空间**：



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- 往往如果 归纳偏好 选对了，可以在短时间内找到答案，否则问题是不可解的 (intractable)

Richard Sutton 的观点

- Richard Sutton 认为，我们只需在 强化学习 的框架下 **增加计算力**，就可以找到 strong AI

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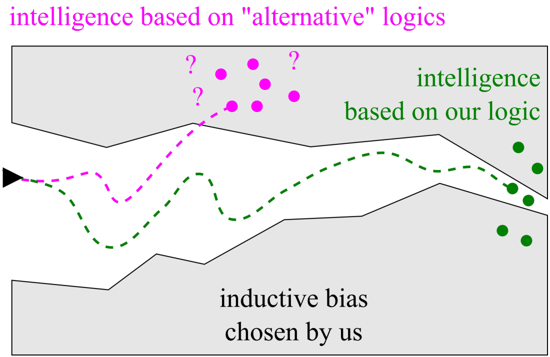
- 我們選擇的只是众多 形式逻辑 之中可能的一种：



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- 这不只是一个「空想」的问题；事实上，世界各地的实验室 已经开始了对 AGI 不同形式的搜索！

对 逻辑主义 的质疑

- 很多人怀疑：人脑真的用 形式逻辑 思考吗？
- We tend to think there are "little models" inside our heads from which we draw inferences.
- If we're given a description: "woman finds new lover, murders husband":

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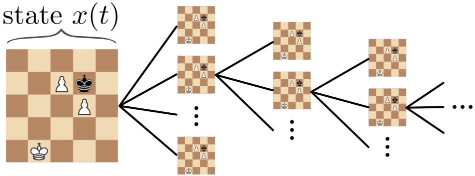
We may not know: Is the woman blonde? What is she wearing?
- In other words, the "model" is devoid of details and our representation seems to be just a sequence of symbols.
- 其实人脑比我们想像中更接近逻辑

Reinforcement learning

- Think of the "**state**" in reinforcement learning like a **board positon** in a chess game:



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- Reinforcement learning seeks to maximize the total **rewards** accrued over a (possibly infinite) **time horizon**:

$$\text{maximize } S = \int_0^\infty L \, dt \tag{9}$$

- Such maximization gives the AI **intelligence** because it is often beneficial to **delay** rewards, eg: to plot a clever chess move
- But reinforcement learning is a **brute force** approach; we need to give the model some additional **inductive bias**, eg, in the form of **logical structure**

Structure of logic

- 我的想法是：在深度学习中引入 **逻辑** 的对称性，解决 strong AI 问题
- 因为人的思维 具有 逻辑 的结构，这个 inductive bias 可以帮助我们快速找到 the solution to strong AI
- 逻辑结构很复杂，但最粗略的 symmetry 是 命题的 **可交换律** (commutativity, or permutation invariance):

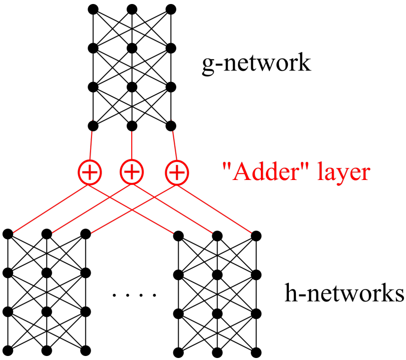
$$\begin{aligned} A \wedge B &\equiv B \wedge A \\ \text{下雨} \wedge \text{失恋} &\equiv \text{失恋} \wedge \text{下雨} \end{aligned} \tag{10}$$

- 它的重要性类似於 视觉中的 平移不变性
- 另一种讲法是：它将智能系统的 **思维状态** (mental state) 分拆成 一粒粒独立的 **命题** (propositions)

Symmetric neural networks

- Permutation invariance can be handled by **symmetric** neural networks
- 我浪费了两年时间试图解决这问题，却发现在 3 年前已经有两篇论文解决了 [PointNet 2017] [DeepSets 2017]，而且数学水平比我高很多
- Any symmetric function can be represented by the following form (a special case of the Kolmogorov-Arnold representation of functions):

$$f(x, y, ...) = g(h(x) + h(y) + ...) \tag{11}$$



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- Sym NN gives a powerful boost in efficiency $\propto n!$ where $n = \#\text{inputs}$
- The code for Sym NN is just a few lines of Tensorflow:

```
h = Dense(3, activation='tanh')
ys = []
for i in range(9):
    ys.append( h(xs[i]) )
y = Keras.stack(ys, axis=1)
Adder = Lambda(lambda x: Keras.sum(x, axis=1))
y = Adder(y)
g = Dense(3)
output = g(y)
```

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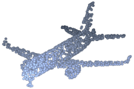
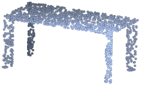
- Very easy to adopt this to existing models such as BERT and reinforcement learning
- I have successfully tested it on the game of TicTacToe: https://github.com/Cybernetic1/policy-gradient

For example: symmetric NN for object recognition

- Imagine objects represented as **point clouds**:



$\xmapsto{f}$ “aeroplane”

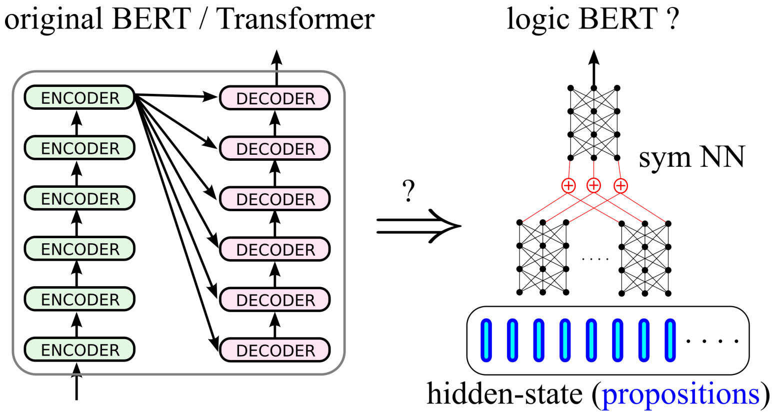


$\xmapsto{f}$ “desk”

- It does not matter **in what order** the points are in a sequence; the function $f(x_1, ..., x_n)$ is symmetric in its arguments (the points)
- Permutation invariance is **essential** for this to work

BERT 的逻辑化

- 类似地，可以将 BERT 的 隐状态 变成 “set of propositions” 的形式，方法是将 原来的 decoder 变成 sym NN：



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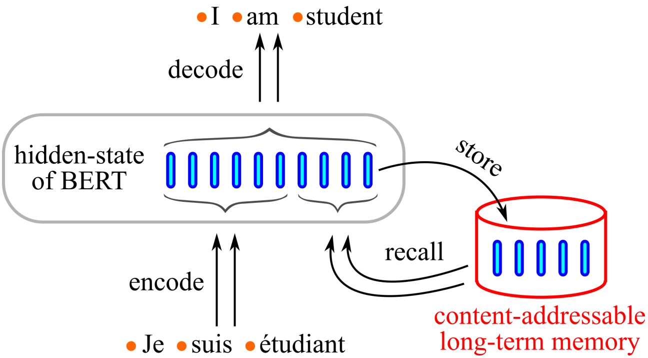
- 原来的 encoder 可以照旧使用，因为后半部改变了，error propagation 会令 representation 也改变
- 当然，这个想法有待实验证实 ☺️

Advantages of logical AI (1)

- With logic, it becomes easy to design cognitive architectures, eg: long-term memory module



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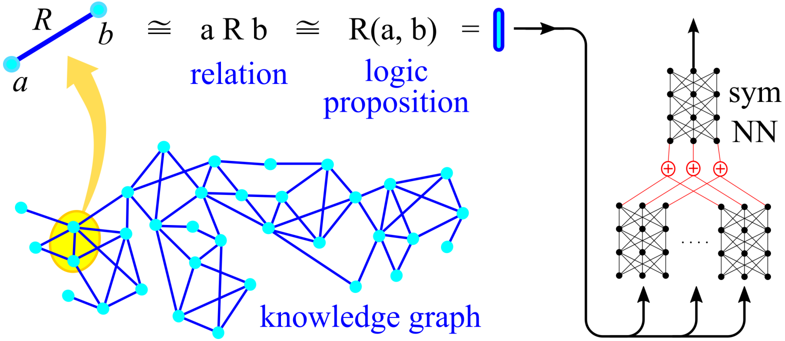
Advantages of logical AI (2)

- 知识图谱 不能直接输入神经网络，它必需分拆成很多 edges，每个 edge 是一个 **关系**，也是一个 **逻辑命题** ；也可以说 “graphs are isomorphic to logic”
- graphs are made up of edges,
  edges = relations between nodes = propositions:



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AGI 理论的突破

- 最近我成功地描述了 strong AI 和 逻辑之间的数学关系
  这种数学关系是永恒不变的，它可以指导日后 AGI 的发展
  请参看附件:《再谈一次 AI 的逻辑结构》
- 关於 Logic BERT 与 attention 的详细理论
  可参看附件《Logic BERT》

References

多谢收看 ☺️

Illustration credits:

- Translation invariance, from Udacity Course 730, Deep Learning (L3 Convolutional Neural Networks ▷ Convolutional Networks)