Foundation of Artificial Intelligence

人工智能基础

李翔宇

软件学院

Email: lixiangyu@bjtu.edu.cn

Introduction to Knowledge Engineering

- Basic concepts of Knowledge Engineering
- Knowledge Representation

Basic concepts of Knowledge Engineering

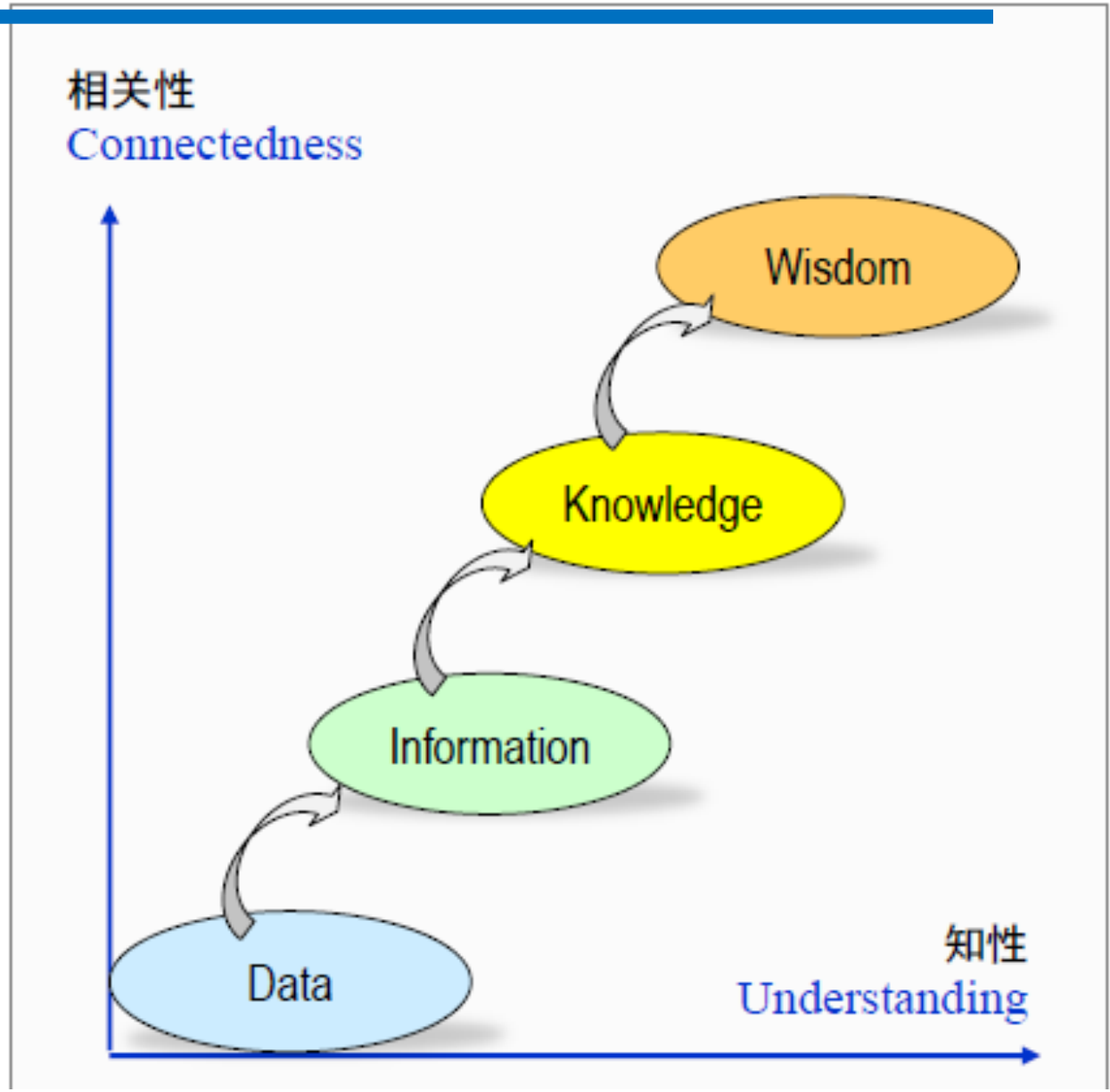
- Data, Information, Knowledge and Wisdom
- Explicit and Tacit Knowledge （显性与隐性知识）
- Knowledge Types
- Knowledge Base and Knowledge Base System
- Knowledge Engineering (KE)

Data, Information, Knowledge and Wisdom
数据、信息、知识与智慧

Data **数据**	**It is the measures and representation of the world.** 世界的计量和表征。 **It is expressed as fact, signal, or symbol.** 表现为事实、信号、或者符号。
Information 信息	It is produced by assigning **meaning** to data. 信息是对数据赋予含义而生成。 Types: Structural vs. functional, subjective vs. objective. 信息的类型：有结构的与功能的，主观的与客观的。
Knowledge 知识	It is formed by processing the information. 知识是对信息进行加工而形成的。 **It is expressed as** processed, procedural, or propositional.对信息 表现为加工的、过程的或者命题的知识。
Wisdom 智慧	It is the experience to make decisions and judgments. 智慧是作出明智的决定和判断的经验。 **It is expressed as** “know-why”, “know-how”, or “why do”. 表现为“知因”、“知然”、或“因何”。

Example: in Bank 在银行

- **Data 数据**
  The numbers 100 or 5 (out of context)
  数字100或者5（无上下文）
- **Information: 信息**
  Principal amount: $100,
  interest rate: 5%
  本金：100美元；利率：5%
- **Knowledge: 知识**
  At the end of year I get $105 back
  年底拿回105美元
- **Wisdom: 智慧**
  Investment need wisdom. How to invest? 投资决策需要智慧。



Concept of Knowledge

- **Human intelligence is mainly to acquire and use knowledge. Knowledge is the foundation of intelligence.**

  人类的智能活动主要是获得知识并运用知识。知识是智能的基础。

- **In order for a computer to be intelligent and capable of simulating human intelligence, it must be equipped with knowledge.**

  为了使计算机具有智能，能模拟人类的智能行为，就必须使它具有知识。

- **However, knowledge needs to be represented by appropriate patterns in order to be stored in computers. Therefore, the representation of knowledge has become a very important research topic in artificial intelligence.**

  但知识需要用适当的模式表示出来才能存储到计算机中去，因此，知识的表示成为人工智能中一个十分重要的研究课题。

Concept of Knowledge

- **Knowledge is the cognition and experience of the objective world accumulated in the long life and social practice and in the scientific research and experiment.**

  知识：在长期的生活及社会实践中、在科学研究及实验中积累起来的对客观世界的认识与经验。

- **Knowledge is the information structure formed by associating relevant information together.**

  知识：把有关信息关联在一起所形成的信息结构。

- **Knowledge reflects the relationship between things in the objective world.**

  知识反映了客观世界中事物之间的关系.

- **Different things or the relationship of the same things form different knowledge.**

  不同事物或者相同事物间的不同关系形成了不同的知识。

Example of Knowledge

- “Snow is white. ”----------fact (事实知识)
- “If you have a headache and a runny nose, you may have a cold”
  ----------rule（规则知识）

  “如果头痛且流涕，则有可能患了感冒” 。

Explicit and Tacit Knowledge 显性与隐性知识

◆ Explicit knowledge显性知识

- It can be expressed into formal language, including grammatical statements, etc. 可以表示为形式语言，包括语法陈述、数学表达式、等等。
- It can be readily transmitted to others. 可以快捷地转化成其它形式。
- It can be easily represented using computer languages, decision trees and rules. 可以容易地用计算机语言、决策树和规则等表示。

◆ Tacit knowledge隐性知识

- It can be individual experience and intangible factors, such as perspective, and belief etc. 可以是个人的经验和无形的因素、如观点、信仰等等。
- It is hard to express using formal language.难以用形式化语言来表示。
- Neural network offers a method to represent tacit knowledge.
  神经网络提供了表示隐形知识的方法。

Knowledge Types 知识的类型

Types 类型	Features 特点
Static knowledge 静态知识	Unlikely to change 不太可能改变
Dynamic knowledge 动态知识	Records in a database 记录在数据库中
Surface knowledge 表层知识	Accumulated through experience 通过经验积累
Deep knowledge 深层知识	Theories/Proofs/Problem Specifics 理论 / 证明 / 问题细节
Procedural knowledge 过程性知识	Describes how a problem is solved 描述如何解决问题
Declarative knowledge 陈述性知识	Describes what is known about a problem 描述已知的问题是什么
Meta-knowledge 元知识	Describes knowledge about knowledge 描述知识的知识
Heuristic knowledge 启发式知识	A rule of thumb that guide the reasoning process 引导推理过程的经验法则

Knowledge Base and Knowledge Base System
知识库和知识库系统

- **The term ‘knowledge base (KB)’ was to distinguish from the more common widely used term ‘database (DB)’. Store data vs. store knowledge**
  “知识库(KB)”这个术语是用于区分更广泛使用的术语 “数据库(DB)”。
- **KB is used to store complex structured and unstructured knowledge. It consists of a set of sentences, each one is expressed in a language called a knowledge representation language and represents some assertion about the world.**
  知识库被用于存储复杂的结构和非结构化知识。它由一套语句组成，每个语句都由知识表示语言来表示的，从而表示关于世界的某些断言。
- **A KB system (KBS) consists of a KB and an inference engine, where, KB represents facts about the world, inference engine can reason about those facts.** 一个知识库系统(KBS) 由知识库和推理引擎组成，其中，知识库表示关于世界的事实，推理引擎则可以基于这些事实进行推理。**Like DB vs. DBS**

Knowledge Engineer 知识工程

- **KE refers to all technical, scientific and social aspects involved in building, maintaining and using KB systems.**

  KE指的是指建立、维护和使用知识库系统所涉及的所有技术、科学和社会方面。

- **KE is essentially engineering on the basis of knowledge models, that use knowledge representation to represent the artifacts of the design process. The initial use of the KE was expert systems.**

  KB本质上是在知识模型基础之上的工程，它采用知识表示来表征设计过程的产品。KB最初的应用是专家系统。

Knowledge Representation 知识表示

- Overview of Knowledge Representation
- Typical Methods of Knowledge Representation
- Semantic Network （语义网络）
- Representation Using Logic（逻辑表示）

Overview of Knowledge Representation

What is knowledge representation 什么是知识表示

- It focus on representing information about the world in a form that a computer system can utilize to solve complex tasks..

  知识表示关注于表示有关世界的信息，以一种计算机系统可用于解决复杂任务的形式表示知识。
- Knowledge representation incorporates findings from psychology about how humans solve problems and represent knowledge in order to design formalisms that will make complex systems easier to design and build.

  知识表示结合心理学中关于人类如何解决问题的研究结果，设计表示知识的形式化，这将使得复杂系统更容易设计和建造。
- Knowledge is stored in KB. And knowledge representation can be used in expert systems.

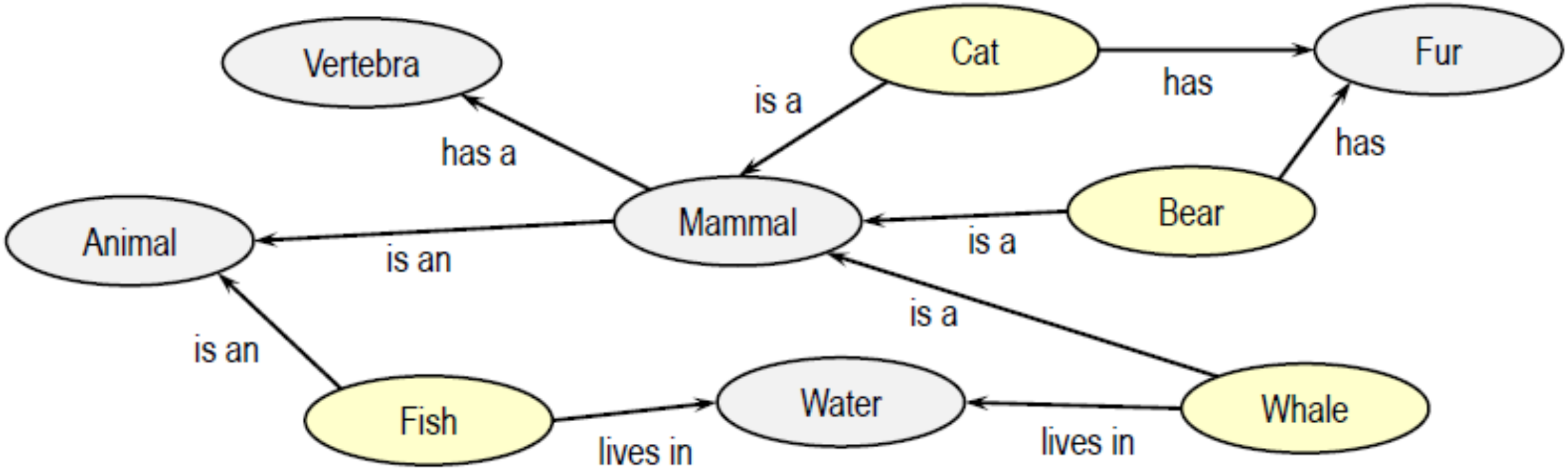
  知识被存放于知识库中。知识表示可被用于专家系统。

Typical Methods of Knowledge Representation

- **Semantic Network** 语义网络
- **First-order logic representation** 一阶逻辑表示
- **Production system** 产生式 系统
- **Frame-based System** 基于框架的系统（框架理论）
- **Bayesian Network** 贝叶斯网络
- **Ontology** 本体

Semantic Network

- Semantic Network is network which represents semantic relations between concepts.
  语义网络是一种表示概念间语义关系的网络。
- It is a directed or undirected graph consisting of nodes and arcs, where nodes represent concepts, arcs denote semantic relationship between the concepts.
  它是由节点和弧组成的有向或无向图，其中，节点：表示概念，弧：概念间的语义关系



Basics of Semantic Network 语义网络基本概念

- Semantic networks are cognitively based, organized into a taxonomic hierarchy.
  语义网络是基于认知的，被组织成为一个分类层次结构。
- A semantic network is used when one has knowledge that is best understood as a set of concepts that are related to one another.
  当某种知识可以很好地理解为一组彼此相关的概念时，则采用语义网表示。
- But, it is intractable for large domains, and can not represent performance very well.
  但是，它难以驾驭大型领域，并且不能很好地表现性能。
- Some properties are not easily expressed, e.g., negation, disjunction, or general non-taxonomic knowledge.
  它也不易表达某些特性，例如：否定、析取、或者一般的非分类知识。

Representation Using Logic 逻辑表示

- **Procedural vs. Declarative Approaches** 过程性与陈述性方法
- **Five Different Logics** 五种不同的逻辑
- **Logical Symbols** 逻辑符号
- **Propositional Logic vs. First-order Logic**命题逻辑与一阶逻辑
- **Formation Rules in First Order Logic** 一阶逻辑的形式规则
- **Prolog Language** Prolog语言

Procedural vs. Declarative Approaches

- **Procedural approaches** 过程性方法

  Procedural knowledge is expressed by procedural approaches, using procedural languages, such as C/C++/C#/Java， Lisp， Python

  过程性知识采用过程性方法描述，即采用过程性语言描述。

- **Declarative approaches** 陈述性方法

  Declarative knowledge is expressed by declarative approaches, using declarative languages, such as

  陈述性知识采用陈述性方法描述，即采用陈述性语言，例如

  - Propositional logic, 命题逻辑
  - First-order logic, 一阶逻辑
  - Temporal logic. 时序逻辑

Five different Logics

- 本体论约定是指世界存在什么 Ontological refers to What's there in the world?
- 认识论约定是指agent认为的事实是什么 Epistemological refers to What does agent think is the truth?

Formal Language 形式语言	Ontological Commitment 本体论约定	Epistemological Commitment 认识论约定
Propositional logic命题逻辑	Facts 事实	true/false/unknown 事实为：真/假/未知
First-order logic 一阶逻辑	facts, objects, relationship 事实、对象、关系	true/false/unknown 真/假/未知
Temporal logic 时序逻辑	facts, objects, relationship, times 事实、对象、关系、时间	true/false/unknown 真/假/未知
Probability theory 概率论	Facts 事实	degree of belief $\in$[0, 1] 可信度：多大的概率可信
Fuzzy logic 模糊逻辑	facts with degree of truth $\in$[0, 1] 事实具有真实度	known interval value 已知区间值

Logical Symbols逻辑符号

Logical Symbols is used in formal representation of Logic.

Category 类别	Symbol 符号	Mean 含义	
Connectives 连接词	¬	not	非
	∧	and	与
	∨	or	或
	⇒	implies	蕴含
	⇔	if and only if (≡)	当且仅当
	⊨	entailment	导出
	⊭		
Quantifiers 限量词	∀	for all	所有
	∃	there exist	存在
Equality 等量词	=	equal	等于

Propositional Logic vs. First-order Logic

- **Propositional logic**: 命题逻辑
  - **A proposition is a declarative sentence that is neither true nor false.**
    命题是一个非真既假的陈述句。如：用P表示“西安是一座古老的城市”这个命题
  - **also known as propositional calculus**, 亦被称为命题演算
  - **Only use logical connectives, deal with simple declarative propositions (if they are true or false).**
    仅使用逻辑连接词，用于处理简单的陈述性命题。
- **First-order logic**: 一阶逻辑
  - **also known as first-order predicate calculus**, 亦被称为一阶谓词演算
  - **additionally, use quantifiers, equality, and use predicates (often associated with sets).**
    除了连接词，还使用限量词（∃、∀）、等量词（=）、以及谓词（通常与集合相关）。如：用谓词 **S(x)** 表示**x**是个学生。

Propositional Logic Syntax with BNF
用BNF表述的命题逻辑语法结构和规则

$$
\begin{aligned}
\textit{Sentence} &\rightarrow \textit{AtomicSentence} \mid \textit{ComplexSentence} \\
\textit{AtomicSentence} &\rightarrow \textit{True} \mid \textit{False} \mid P \mid Q \mid R \mid \ldots \\
\textit{ComplexSentence} &\rightarrow < \textit{Sentence} > \mid [\ \textit{Sentence}\ ] \\
&\mid \neg\, \textit{Sentence} \\
&\mid \textit{Sentence} \wedge \textit{Sentence} \\
&\mid \textit{Sentence} \vee \textit{Sentence} \\
&\mid \textit{Sentence} \Rightarrow \textit{Sentence} \\
&\mid \textit{Sentence} \Leftrightarrow \textit{Sentence} \\
\textit{OPERATOR PRECEDENCE} &: \neg, \wedge, \vee, \Rightarrow, \Leftrightarrow
\end{aligned}
$$

BNF: Backus–Naur Form
巴科斯-诺尔范式

First-Order Logic Syntax with BNF
用BNF表述的一阶逻辑的语法规则

$$
\begin{aligned}
\textit{Sentence} &\rightarrow \textit{AtomicSentence} \mid \textit{ComplexSentence} \\
\textit{AtomicSentence} &\rightarrow \textit{Predicate} \mid \textit{Predicate}(\textit{Term}, \ldots) \mid \textit{Term} = \textit{Term} \\
\textit{ComplexSentence} &\rightarrow (\textit{Sentence}) \mid [\textit{Sentence}] \mid \neg \textit{Sentence} \mid \textit{Sentence} \wedge \textit{Sentence} \\
&\mid \textit{Sentence} \vee \textit{Sentence} \mid \textit{Sentence} \Rightarrow \textit{Sentence} \mid \textit{Sentence} \Leftrightarrow \textit{Sentence} \\
&\mid \textit{Quantifier Variable}, \ldots \textit{Sentence} \\
\textit{Term} &\rightarrow \textit{Function}(\textit{Term}, \ldots) \mid \textit{Constant} \mid \textit{Variable} \\
\textit{Quantifier} &\rightarrow \forall \mid \exists \\
\textit{Constant} &\rightarrow A \mid X_1 \mid \textit{John} \mid \ldots \\
\textit{Variable} &\rightarrow a \mid x \mid s \mid \ldots \\
\textit{Predicate} &\rightarrow \textit{True} \mid \textit{False} \mid \textit{After} \mid \textit{Loves} \mid \textit{Raining} \mid \ldots \\
\textit{Function} &\rightarrow \textit{Mother} \mid \textit{LeftLeg} \mid \ldots \\
\textit{OPERATOR PRECEDENCE} &: \neg, =, \wedge, \vee, \Rightarrow, \Leftrightarrow
\end{aligned}
$$

Formation Rules in First Order Logic

- The formation rules define 该形式规则定义
  - **Terms** 项
  - **formulas** 公式
- The formation rules can be used to write a formal grammar for terms and formulas.
  该形式规则可以用于书写项和公式的形式文法。
- Formation rules are generally context-free, i.e.,
  形式规则通常是上下文无关的，即
  each production has a single symbol on the left side.
  每个产生式左侧有一个单一的符号。

Formation Rules of First Order Logic : Terms
一阶逻辑的形式规则：项

- **Rule1: Variables** （变量）

  Any variable is a term. 任何变量都是一个项。

- **Rule2: Constants** （常数）

  Any constant is also a term. 任何常数也都是一个项。

- **Rule3: Functions** （函数）

  Any expression *f*(*t*1,...,*tn*) of *n* arguments is a term, where each argument *ti* is a term, and *f* is a function symbol of valence *n*. In particular, symbols denoting individual constants are 0-*ary*function symbols, and are thus terms.

  任何n个参数的表达式f(t1,...,tn)都是一个项，其中每个参数ti是一个项，并且f是一个价n的函数符号。尤其是，表示个体常量的符号是0元函数符号，因此也是一个项。

Formation Rules of First Order Logic : Formulas
一阶逻辑的形式规则：公式

- Predicate symboles. If P is an *n-ary* predicate symbol and $t_1,...t_n$ are terms, then $P(t_1,...t_n)$ is a formula.

  谓词符号：若P是一个n元谓词符号并且$t_1,...t_n$是项，则 $P(t_1,...t_n)$ 是一个公式。

- Equality. If the equality symbol is considered part of logic, and t_1 and t_2 are terms, then $t_1=t_2$ is a formula.

  等量：若等量符号被认为是逻辑的一部分，并且 t_1和 t_2是项，则 $t_1=t_2$ 是一个公式。

- Negation. If φ is a formula, then $\neg\varphi$ is a formula.

  否定：若φ 是一个公式，则 $\neg\varphi$ 是一个公式。

- Binary connectives. If φ and ψ are formulas, then $(\varphi \Rightarrow \psi)$ is a formula. Similar rules apply to other binary logical connectives.

  二元连接：若φ 和 ψ 是公式，则 $(\varphi \Rightarrow \psi)$是一个公式。类似的规则可用于其他二元逻辑连接。

- Quantifiers. If φ is a formula and x is a variable, then $\forall x\varphi$ and $\exists x\varphi$ are formulas.

  限量：若φ 是一个公式并且x是一个变量，则 $\forall x\varphi$ 和 $\exists x\varphi$ 是公式。

Prolog Language Prolog语言

- Prolog (Program in logic) language has its roots in first-order logic.
  Prolog语言起源于一阶逻辑。
- Prolog is a general purpose **logic programming** language, has been used for theorem proving, expert systems, natural language processing, and so on.
  Prolog是一种通用的逻辑编程语言，已经被用于定理证明、专家系统、自然语言处理，等等。
- Unlike other programming languages(C, C++), Prolog is declarative: the program logic is expressed in terms of relations, represented as facts and rules.
  不同于其它过程性编程语言（C，C++），Prolog是陈述性的：程序逻辑由关系来表达，表示为事实与规则。

Prolog语句

likes (bill, car). 表示bill喜欢汽车，是事实性知识
animal(X) : -cat(X). X是猫，因此X是动物，这是规则性知识
bird(X) :-animal(X), has(X, feather).
X是动物，X还有羽毛，因此X是鸟。这也是规则性知识。

Thank you !